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T. RYAN,
Director-General. W 167

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Acting Clerk to the Board. W 148

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6.	Axleboxes	10s.
7.	Water Cranes	7s. 6d.
8.	Bellows	5s.

Specifications and Forms of Tender may be obtained at this office on payment of the fee for the Specification, which payment will not be returned.
The fee should accompany any application by post. Cheques and Postal Orders should be crossed and made payable to the Great Indian Peninsula Railway Company.
Tenders must be delivered in separate envelopes, sealed and addressed to the undersigned, marked "Tender for Straight Axles," or, as the case may be, not later than Eleven o'clock a.m. on Tuesday, the 12th September, 1922.
The Directors do not bind themselves to accept the lowest or any Tender.

R. H. WALPOLE,
Secretary.

Company's Offices,
48, Copthall Avenue, E.C. 2,
London, 30th August, 1922. W 178

LIVERPOOL CORPORATION WATERWORKS.

NEW TRUNK MAIN FROM PRESCOT: CONTRACT NO. 2.

PIPE LAYING,

The WATER COMMITTEE of the LIVERPOOL CORPORATION are prepared to receive

Tenders from Competent

Persons willing to enter into a Contract for the LAYING OF CAST-IRON PIPES of 42 in. and 40 in. internal diameter and other ancillary works, as follows, viz.:—
From the PRESCOT RESERVOIRS of the Liverpool Corporation TO RATHBONE ROAD, LIVERPOOL, in the county of Lancaster, for a distance of about 6 miles.
The Plans and Sections may be inspected, and copies of the Specification and Form of Tender obtained on and after Monday, the 28th August, 1922, at the Water Engineer's Office, Alexandra Buildings, 55, Dale Street, Liverpool, upon payment of the sum of Five Guineas, which amount will be returned upon receipt of a *bona-fide* tender.
Tenders, endorsed "Tender for Pipe-laying" are to be sent through the Post, in a sealed envelope, addressed "Chairman of the Water Committee, Town Clerk's Office, Municipal Buildings, Liverpool," so as to be delivered not later than Twelve o'clock noon, on Tuesday, the 19th September, 1922.
The Water Committee do not bind themselves to accept the lowest or any other tender.

G. HAMMOND ETHERTON,
Town Clerk.

Municipal Buildings,
Liverpool,
25th August, 1922. W 191

STATE ELECTRICITY COMMISSION OF VICTORIA.

TENDERS FOR PLANT.

Tenders are Hereby In-

vited for the SUPPLY, DELIVERY, etc., of the following for the Morwell Power Scheme.
Copies of Tender Form and Specification will be available upon application to:—
AGENT-GENERAL FOR VICTORIA,
Melbourne Place,
Strand,
London, W.C. 2.

SPECIFICATION No. 282—COAL HANDLING PLANT FOR MORWELL POWER STATION AND BRIQUETTING WORKS.
CHARGE:—
£2 2s. for the first two copies of Tender Form, Conditions of Contract, Specification and Drawings complete. These charges will be returned on receipt of a *bona fide* Tender. A third copy and any further copies will be supplied for the sum of £1 1s. each.
PRELIMINARY DEPOSIT.
A Preliminary Deposit of £50 is to be lodged with Tender.
The Specifications may be inspected at the above-mentioned office.
The Commission does not bind itself to accept the lowest or any Tender.
Tenders on prescribed form, properly endorsed and addressed, must be delivered to the undersigned in Melbourne not later than Five p.m., 18th December, 1922.

R. LIDDELOW,
Secretary.

State Electricity Commission of Victoria,
Melbourne,
Victoria,
Australia. W 96

THE CANADIAN-PACIFIC LINER "EMPRESS OF CANADA."

THE twin-screw geared turbine passenger steamer Empress of Canada, which has recently been completed by the Fairfield Shipbuilding and Engineering Company, Limited, Govan, Glasgow, to the order of the Canadian-Pacific Railway Company (Managers — Canadian-Pacific Steamships, Limited) for their mail, passenger and cargo service between Vancouver and the Far East, forms the most important addition yet made to the supervision of Sir J. H. Biles and Co., who, together with the builders, have given careful consideration to the special requirements of the trade for which she has been built.

The leading particulars of the vessel are :—

Length overall	653 ft. 4 in.
Length B.P.	625 ft.
Breadth, moulded	77 ft. 6 in.
Depth, moulded to bridge deck ...	53 ft. 6 in.
Height from keel to boat deck level	70 ft.
Draught, loaded	28 ft. 10 in.
Speed on service	18 knots.
Gross tonnage	21,520 tons.

classed "100 A1 ✠ Shelter Deck with Freeboard." The vessel is subdivided in full accordance with the requirements of the Bulkhead Convention, and fulfils all the requirements of the International Conference on Safety of Life at Sea, 1914. She also meets all British Board of Trade and Home Office Factory Act requirements and complies with both American and Canadian laws for passenger steamers.

A prominent feature of the ship's external appearance, which is well shown by the photograph reproduced in Fig. 1 subjoined, is her

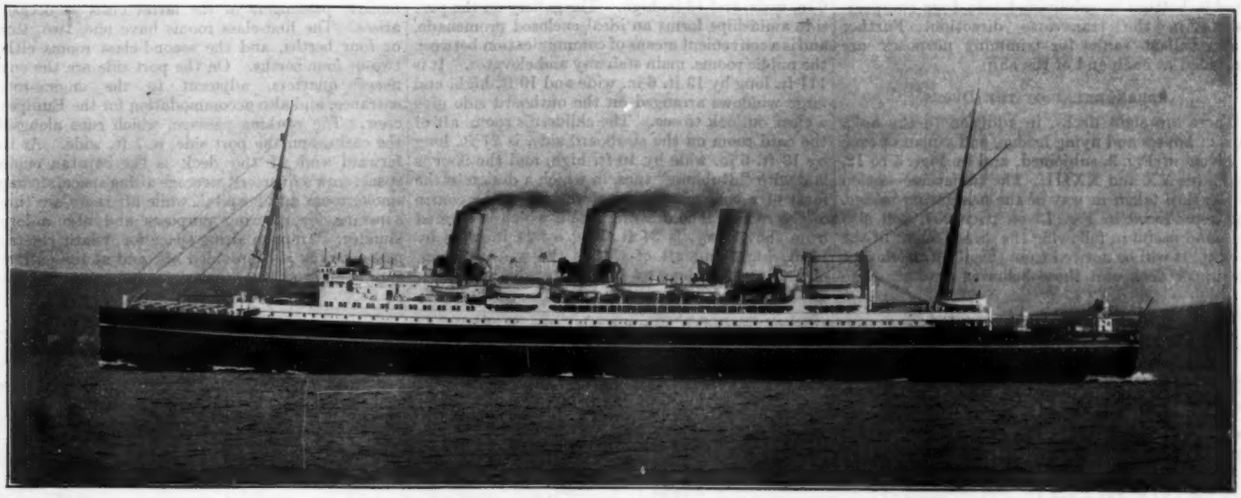


FIG. 1. THE VESSEL ON TRIAL.

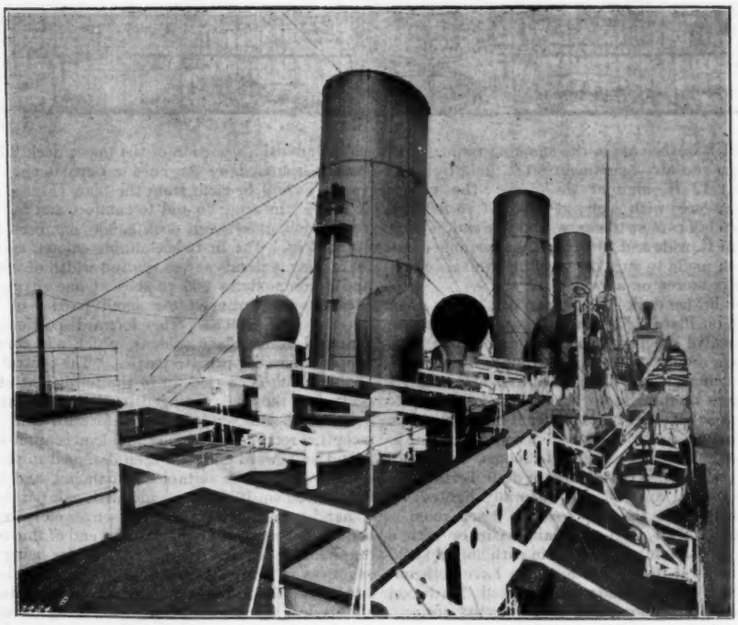


FIG. 2. DECK HOUSES AND BOAT DECK.

that company's fleet. She is the largest merchant ship so far produced at the Fairfield Company's yard on the Clyde, and will be the largest mail and passenger steamer running on the Pacific. Her double-reduction gearing is, we understand, the most powerful yet completed for the merchant service. The vessel was designed by the Fairfield Company to meet the owners' requirements for her intended service, and in accordance with arrangement plans supplied by the owners' naval architect, Mr. Hugh R. Macdonald. She was constructed under

Passengers—	
First class	488
Second class	106
Third class	238
Asiatic steerage	926
Officers and crew	552
Total	2,310

The Empress of Canada has been constructed under special survey in accordance with the requirements of the highest class of Lloyd's Register of Shipping, by whom she has been

three funnels, of which the aftermost is situated over the engine casing, and serves to improve her general appearance as well as for ventilation purposes. There are four decks extending the full length of the vessel: the bridge deck B, shelter deck C, upper deck D, and main deck E. Beneath the main deck, and outside the limits of the machinery space, are two further decks—the lower deck F and orlop deck G. The 'tween decks between the shelter and bridge decks are enclosed by side-plating for nearly the full length of the ship, there being only a short portion of the bridge deck right aft carried on open stanchions. Above the bridge deck are the promenade deck A and the boat deck, both having a long extension over the 'midship portion of the vessel, and being 475 ft. and 340 ft. in length, respectively. The sides are plated in between the bridge and the promenade decks, but the boat deck is carried at the sides on open stanchions, except for a length of about 100 ft. at the forward end of the erection, where there are side screens with sliding windows. On the promenade deck are large deckhouses, the structure of which is thoroughly united to the main hull by numerous webs and partial bulkheads.

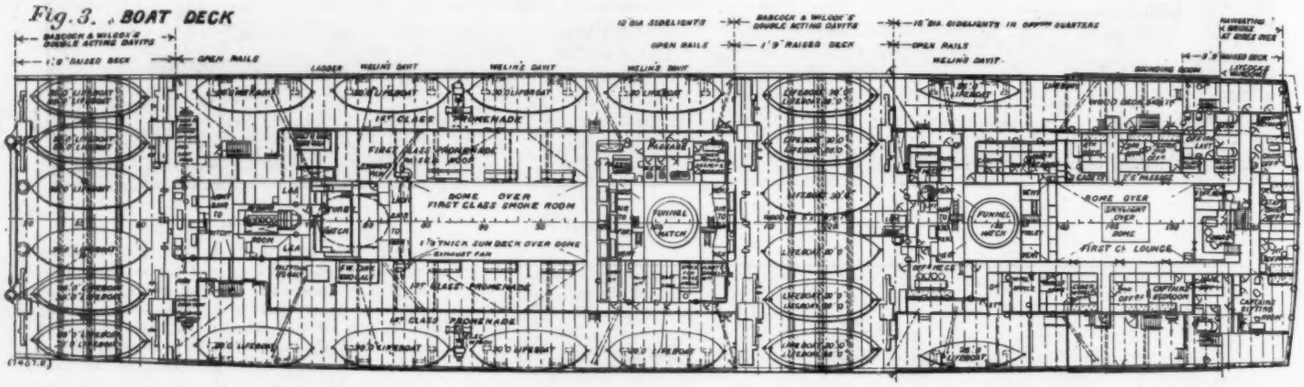
The stern is of cruiser form, but it is continued further aft at the uppermost decks to avoid a flattened appearance at this part, and is associated with a rudder of the underhung balanced type. The lower part of the main hull ends at the propeller brackets, so that there is virtually an aperture in way of the propellers, the latter being arranged just forward of the rudder. The whole arrangement will be clear from an examination of the sectional profile of the vessel reproduced in Fig. 4 on Plate XX in conjunction with the hold plan, Fig. 12 on Plate XXIII. The main transverse watertight bulkheads extend to the shelter deck C, and are 10 in number. The middle portion of the ship below E deck is occupied by the turbine room, boiler rooms, and oil-fuel bunkers, the ship being arranged primarily to burn oil fuel; coal-shoots are, however, arranged along the sides to permit reversion to coal if necessary. The boilers are placed in two separate boiler rooms of identical arrangement, separated from each other and from

the turbine room by cross bunkers, and there is also a cross bunker separating the forward boiler room from the forward lower holds. The arrangement and subdivision of the oil-fuel bunkers will be seen from the plans of the lower deck, orlop deck and hold reproduced in Figs. 10 to 12 on Plate XXIII. The double bottom, from the after cross bunker to the forepeak bulkhead, is also arranged to carry fuel oil alternatively to water ballast. The after portion of the double bottom is available for water ballast or alternatively for fresh water for boiler-feed and other purposes. Within the range of the machinery space the double bottom is subdivided into four compartments in the transverse direction. Further water-ballast tanks for trimming purposes are provided at each end of the ship.

ARRANGEMENT OF THE DECKS.

There are eight decks, in addition to the hold, tops of houses and flying bridge, and a plan of each is given in Fig. 3, subjoined, and in Figs. 5 to 12, on Plates XX and XXIII. The transverse section of the ship taken in way of the navigating bridge, and reproduced in Fig. 13 on page 257, will also be found useful in following the arrangement of the decks. It will be noticed from this illustration that the upper deck and those below it are flat, while

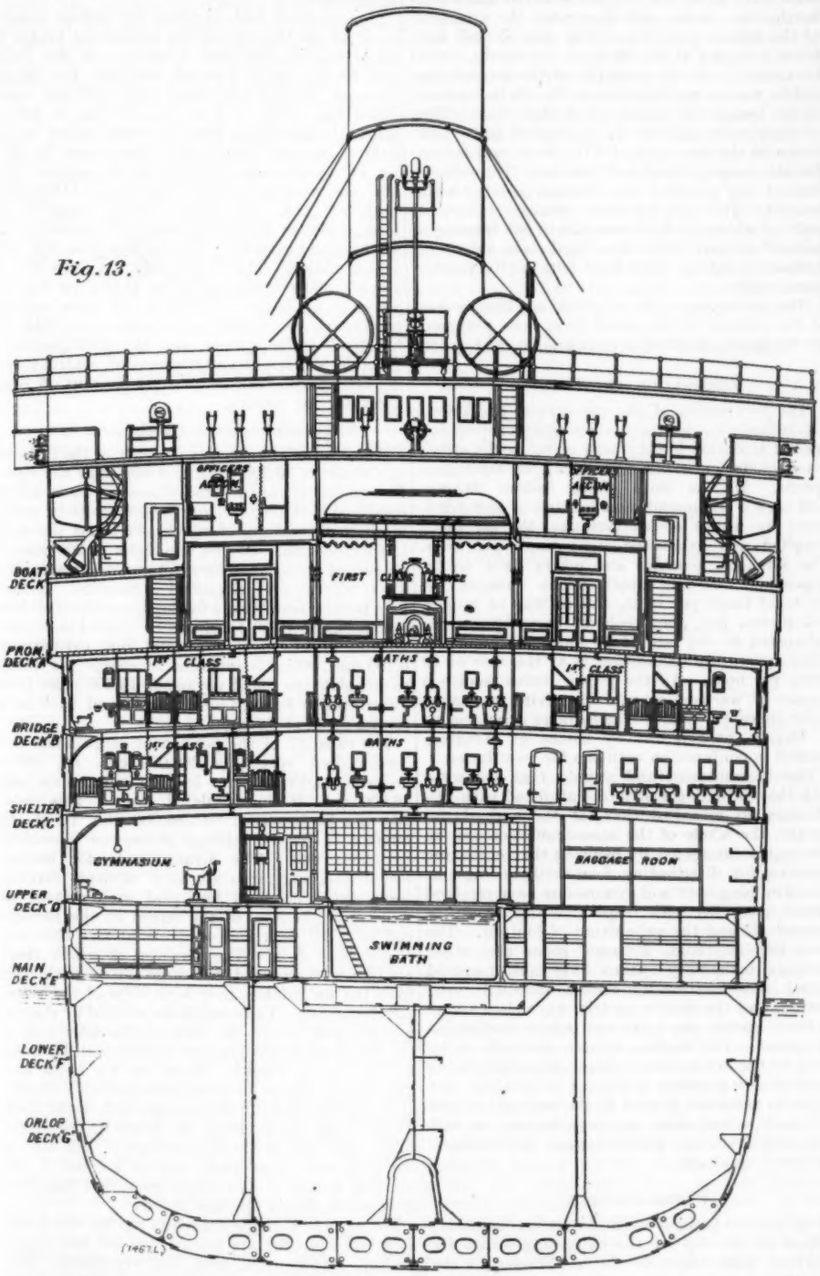
Fig. 3. BOAT DECK


BABCOCK & WILCOX'S DOUBLE ACTING DAVITS
1'6" RAISED DECK
OPEN RAILS
LADDER
WELIN'S DAVIT
10 DIA SIDELIGHTS
1'9" RAISED DECK
15" DIA SIDELIGHTS IN OFFrs QUARTERS
NAVIGATING BRIDGE AT SIDES DECK
9'3" RAISED DECK
LIFEBOAT
BRIDGING DECK
1ST CLASS PROMENADE
GLAZED
DOME OVER FIRST CLASS SMOKE ROOM
1'0" THICK SUN DECK OVER DOME
EXHAUST FAN
FUNNEL
FIRST CL LOUNGE
DOME OVER SKYLIGHT OVER 1ST DOME
CAPTAIN'S CABIN
CAPTAIN'S SITTING ROOM
LIFEBOAT 30' 0"
LIFEBOAT 30' 9"
LIFEBOAT 30' 0"
LIFEBOAT 30' 0"
LIFEBOAT 30' 0

there are 15 third-class staterooms, a large dining and airing space for steerage passengers, and also the steerage kitchen. The rooms are generally arranged with four berths and are fitted with open wash basins having cold water laid on.

The main deck "E" Fig. 9, Plate XXIII, gives accommodation for 176 third-class passengers in portable cabins, and 582 steerage passengers in portable open berthing, which spaces can be used for cargo if required; accommodation is provided

Fig. 13.



amidships and at the after end for the Asiatic crew. Immediately below the kitchen are the ship's stores, including insulated provision chambers, and electric lifts are fitted to enable the stores to be taken up to the kitchen on the upper deck. Aft of the ship's stores a large space is provided for the carriage of silk. The lower deck "F" Fig. 10, Plate XXIII, is generally used for cargo, including silk, but accommodation for 110 steerage passengers is provided in portable open berthing forward. The insulated cargo chambers are situated aft as also is the steering gear compartment. The orlop deck "G" Fig. 11, Plate XXIII, is arranged entirely for cargo, as are also the lower holds, a plan of which is given in Fig. 12, Plate XXIII.

The following table is explanatory of the reference numbers which appear on the sectional profile of the vessel, Fig. 4, on Plate XX:—

INDEX TO SECTIONAL PROFILE.

House Tops—
Chart house ... 1
Wheel house ... 2
Navigating bridge ... 3

Boat Deck—
Contactor house ... 4
Emergency dynamo-room ... 5
Petty officers ... 6
Passage ... 7
Petty officers ... 8
Lift machinery ... 9
Officers' mess ... 10
Petty officers ... 11, 12, 13
Officers' ward-room ... 14
Officers' accommodation ... 15

Promenade Deck A—
Verandah café ... 16
Passage ... 17
Bar ... 18
1st class smoking-room ... 19
1st class writing-room ... 20
" " drawing-room ... 21
" " entrance ... 22
Children's room ... 23
Card-room ... 24
1st class lounge ... 25
" " promenade ... 26

Bridge Deck B—
2nd class lounge ... 27
Ship's office ... 28
1st class accommodation ... 29
Barber's shop ... 30
Office ... 31
Bureau ... 32
1st class stairway and electric elevator ... 33
Steerage entrance ... 34

Shelter Deck C—
Hospital bathroom ... 35
Laundry ... 36
3rd class entrance ... 37
2nd class accommodation ... 38
Cargo hatchway ... 39
Locker ... 40
Well over 1st class dining-saloon ... 41
Musicians' gallery ... 42
Steerage airing space ... 43
Padded room ... 44
Carpenter's shop ... 45
Capstan engine space ... 46

Upper Deck D—
Steerage kitchen and pantry ... 47
Entrance to steering gear ... 48
Steerage airing and dining space ... 49
3rd class accommodation ... 50
Entrance to 2nd class and 3rd class dining-saloons ... 51
Bar ... 52
Bread-room ... 53
Passage ... 54
1st, 2nd and 3rd class kitchen ... 55
1st class pantry ... 56
1st class still-room ... 57
Linen-room ... 58
1st class dining-saloon ... 59
" " reception-room ... 60
Cloak-room ... 61
Dressing-room ... 62
Vestibule ... 63
Swimming bath ... 64
Passage ... 65
Steerage accommodation ... 66
Seamen's accommodation ... 67

Main Deck E—
Petty officers ... 68
Silk-room ... 69
Dry store ... 70
Tea and sugar store ... 71
Flour store ... 72
Poultry store ... 73
Fish store ... 74
Fan-room ... 75
Stewards', &c., accommodation ... 76
Escape from pipe passage ... 77
Canvas room ... 78

Lower Deck F—
Steering gear ... 79
Cargo space ... 80
Egg store ... 81
Fish store ... 82
Meat store ... 83
Poultry store ... 84
Linen-room ... 85
Dynamo-room ... 86
Engine-room ... 87
Steam-pipe passage ... 88
Boiler-room ... 89
Oil fuel ... 90
Boatswain's store ... 91

Orlop Deck G—
Aft peak ... 92
Passage ... 93
Chain locker ... 94
Fore peak ... 95

Hold—
Shaft tunnel ... 96
Engineer's workshop ... 97
Evaporator-room ... 98
Refrigerating machinery ... 99
Pump-room ... 100
Pipe passage ... 101
Searchlight platform ... 102
Crow's nest ... 103

DECORATIVE FEATURES OF THE PUBLIC ROOMS.

The decorative work of the public rooms was designed by Messrs. George A. Crawley and Partners, of London and Glasgow, and has been carried out by the builders and by Messrs. Wylie and Lochhead and Messrs. Trollope and Colls. Dealing first with the rooms on the promenade deck "A," we should mention that the gallery, above referred to, has been made a special feature of the ship. A photograph of this gallery, looking aft, is reproduced in Fig. 19 on Plate XXI, and in this view the main staircase, which opens into the gallery, is

visible on the left. The gallery is furnished with easy chairs and tables, clearly shown in our illustration, and the walls are panelled in polished Cuban mahogany and hung with prints. The entrance to the gallery from the main staircase and passenger lift is well shown in Fig. 21 on Plate XXI. Opposite this entrance is a bookstall, visible in Fig. 19, and arranged so that passengers can be supplied either from the gallery or the outer promenade.

At the forward end of the gallery is the first-class lounge which has been planned so as to provide a large and lofty central space separated from the side portions by arched recesses. An unusual feature in wall decoration is the large brocade panels of rich design set in walnut framing. This feature is well illustrated in Fig. 16 on Plate XIX, which is reproduced from a photograph of the after part of the central space. The room is exceptionally well lighted, both from a large lay light in the dome and through windows on three sides. It is well adapted for dancing and music, and can also be used for kinematograph exhibitions, for which purpose a concealed operating room is provided at the forward end. The floor is laid with oak parquetry, partly covered with carpet runners, and in the marble fireplace, which is well shown in our illustration, an electric "Magicoal" fire is laid.

Opening off the lounge is the first-class card room, which we illustrate in Fig. 17 on Plate XIX. This apartment, the dimensions of which have been given above, is panelled in grey sycamore and is designed in Queen Anne style. As in the case of the lounge, the fireplace is fitted with a "Magicoal" fire and the floor is laid with oak parquetry. The drawing room, which is entered from the gallery, is a large and comfortable apartment, a feature being the decoration of the panels, which are covered in brightly coloured "Toile de Jouy." As will be seen from the photograph of the interior of this apartment, reproduced in Fig. 24 on Plate XXIV, there is a marble fireplace with a "Magicoal" fire, and the floor is laid with oak parquetry and provided with carpet runners. The first-class writing room and children's room each have an effective colouring scheme with painted panels in shaded tones of duck-egg green, with enriched cornice and panel mouldings; the former is illustrated in Fig. 25, Plate XXIV.

The first-class smoking room at the aft end of the gallery has a large lofty central space about 16 ft. in height, and the portions at the ship's sides have been arranged for the accommodation of card parties. The walls of this room, which we illustrate in Fig. 20, Plate XXI, are panelled in oak to a Georgian design, and are sub-divided with finely carved Ionic columns and pilasters; there are large three-light mullioned and transomed windows at the sides. The fireplace, which can be seen in our illustration, is of black and gold marble, and above it is a portrait of Admiral Lord Hawke, by Mr. Phillip Connard; over this is a carved coat-of-arms of Canada. Fig. 18 on Plate XXI shows the verandah café, which is well adapted to the requirements of the service, both in appearance and furnishing. It is painted white and half timbered in oak framing of natural colour, and is also well lighted and aired by opening casement windows. An American soda fountain is installed and the room is furnished with Dryad-cane tables and chairs, the floor being completely laid with "Rublino" tiling.

The first-class dining saloon on "D" deck amidships is Georgian in character and panelled throughout in large painted panels of a light grey tone, having the mouldings shown up in white. The room is well lighted and the whole effect is very pleasing as will be gathered from the photograph reproduced in Fig. 23 on Plate XXII. The musicians' gallery, above referred to, has an ornamental wrought-iron balustrade, clearly shown in our illustration, together with one of the veneered mahogany sideboards, four of which are provided. The reception room, which we illustrate in Fig. 22 on Plate XXII, is decorated in similar style and colour to the dining saloon. The arched recesses at the sides, for the orchestra and for the use of passengers, should be noticed. There are three large arch-headed mirrors at the after end with *jardinières* for flowers in front. These, with the crystal and glass electric fittings make this room particularly attractive.

To illustrate the character of the first-class passenger accommodation, we reproduce in Figs. 26 and 27 on Plate XXIV, views of the interiors of a sitting-room and bedroom of one of the special suites on B deck. The walls of the sitting-room, it will be noticed, are covered with striped "Fantasie" silk of French design. Fig. 28 on the same plate shows the interior of a first-class, two-berth state room and illustrates the character of the fittings provided. The neat electric light fittings placed at the head of the berths should be noticed. As an example of the second-class public rooms, we illustrate in Fig. 29 the interior of the lounge for passengers of that class. This, as previously mentioned, is situated in a deck-house on the after part of "B" deck, and is comfortably arranged and well furnished. The walls are framed and panelled, and finished in ivory-white enamel. The second-class dining saloon is painted white and half timbered in oak framing of natural colour, while the third-class saloon is framed in oak to dado level with white painted panels above.

The photographs from which our illustrations of the interior of the vessel have been prepared, are by Messrs. Bedford Lemere and Co., of London.

VENTILATION AND HEATING.

The ventilation of the passengers' and crew's accommodation has been thoroughly carried out, special attention having been given to the crew's accommodation in the vicinity of the machinery spaces. All the third class, Asiatic steerage and crew's accommodation is warmed and ventilated by means of thermotanks, the air being supplied and exhausted eight times per hour. The kitchens, pantries and offices have an independent cold-air supply which changes the air eight times per hour, and in way of ranges, hot plates, &c., the whole of these spaces are exhausted at the rate of 60 times per hour; in other spaces the exhaustion is at the rate of 30 times per hour. All the public rooms receive a supply of warmed or cold air giving a change eight times per hour. The exhaust arrangement is largely carried out by means of inductors worked in conjunction with the fan ventilation.

The thermotanks and supply fans connected with the ventilating system are all fitted with disinfectors so arranged that, at the end of the voyage, the whole of the accommodation can be thoroughly fumigated by utilising the ventilating trunking for distributing formaldehyde vapour. The swimming bath and gymnasium have received special attention with respect to the supply of warmed air and the exhaustion of foul air. The main turbine room, dynamo room and other auxiliary machinery spaces have also received special consideration to ensure thorough ventilation, and the results on trial have shown that all these spaces are quite cool when working at full power. The heating system generally is by steam on the low-pressure system, the steam being supplied at a pressure of from 5 lb. to 10 lb. per sq. in. to radiators placed in the passages in the first and second-class accommodation, as well as in the first-class public rooms, and officers' and crew's quarters.

WATER SERVICES.

A cylindrical tank, of about 100 gallons capacity, is fitted on the top of the navigating bridge for supplying fresh water to the washbasins in the officers' and crew's cabins. This tank is filled by a 3-in. pipe from pumps in the engine room, and the overflow runs into a 1,000-gallon fresh-water tank on the boat deck. From this tank, the fresh water passes through a filter before being distributed to the washbasins in the suite and special rooms, first and second-class state rooms, bath rooms, public lavatories, engineers' baths and all showers throughout the ship, also kitchens and pantries. There is also a cooled fresh-water service from which supplies are led to all bars and service rooms.

Hot fresh water is laid on to all washbasins in suites and special rooms, first and second-class state rooms, and also to bath rooms, lavatories, &c., throughout the ship, as well as to kitchens and pantries. The water is heated by a Royle's calorifier capable of heating 1,200 gallons from 50 deg. F. to 160 deg. F. per hour, using steam at 5-lb. per sq. in. pressure. From this calorifier, flow and return pipes are led round the ship to bring the circulation as near to the draw-off taps as practicable. By natural circulation, or by means of a pump, a continuous supply of hot water is maintained.

A cylindrical tank of about 300 gallons capacity is fitted on the top of the navigating bridge for supplying the first-class lavatories on the bridge and shelter decks forward, and also the officers' lavatory on the boat deck with cold salt water. From this tank, a 4-in. supply pipe is led for filling the swimming bath, the water being filtered before entering the bath. The tank is filled by a 7-in. pipe from pumps in the engine room, and the overflow is led back to a 1,000-gallon tank on the boat deck, which supplies the bridge, shelter and upper decks aft, as well as the kitchens and calorifier; the overflow from this tank is led through the ship's side. A calorifier of Royle's make is also fitted for supplying hot salt water to the baths. This is of the same capacity as that above referred to in connection with the hot fresh water system, and the arrangement is generally similar. In all the services, control valves are arranged so that sections can be shut off when necessary for repairs.

ARRANGEMENTS FOR CARGO CARRYING.

The deadweight carrying capacity of the Empress of Canada is 10,200 tons, and although the vessel is intended mainly for the passenger trade, about one-third of the latter figure (3,600 tons to be exact) is allotted to cargo, of which silk forms the most important item. Of the remainder, 2,300 tons is accounted for by passengers, stores, and water, and 4,300 tons by oil fuel carried in bunkers. It may here be mentioned that a further quantity of oil fuel, amounting to 1,800 tons, can be carried in double-bottom tanks, making a total fuel capacity of 6,100 tons, which is sufficient to enable the vessel to complete the round voyage of 13,500 miles from Vancouver to Japan, China, Manila and back at a service speed of 18 knots.

The capacity of the permanent cargo holds and 'tween deck spaces is 260,000 cub. ft., which includes 45,000 cub. ft. for the silk rooms and 16,000 cub. ft. for insulated cargo. This capacity can be increased to 380,000 cub. ft. if the number of Asiatic steerage passengers is reduced by about 600. The arrangements for loading and discharging cargo are very efficient, derricks being fitted on both fore and main masts, as well as on the front of the screen at the forward end of "B" deck and on posts at the after end of the boat deck. The derricks, of which there are 15, are so arranged that cargo can be discharged from the six hatches, over both sides of the vessel simultaneously. The derricks are worked by electric winches, and one of the them on the after side of the fore mast is arranged for dealing with loads up to 20 tons in weight. There are six holds and 'tween deck spaces for cargo, arranged with widely-spaced pillars to facilitate stowage, and, in the main 'tween decks, cargo doors are fitted in the ship's sides. The spaces for the carriage of silk are on the main and lower decks, and on account of the valuable nature of this cargo, great care has been exercised in fitting up these spaces.

The insulated cargo chambers are on the lower deck aft, and they are sub-divided for fish, meat, poultry, apples, eggs, fruit and vegetables. The fish, meat and poultry chambers are cooled by brine grids on the roof and walls, and the chambers for fruit and vegetables by brine grids on the walls only. The egg chamber is cooled by brine grids on the walls, and also by air-ducts round the chamber, the air being drawn from the atmosphere by a 20-in. thermotank fan, driven by a 4-h.p. motor, and passed through a brine grid air-cooler to the air-ducts, exhausting again to the atmosphere. Large insulated chambers are arranged on the main deck amidships for the ship's provisions and are brine cooled.

(To be continued.)

THE ANALYSIS OF ISOTROPIC SOLIDITY.

By J. INNES, R.C.N.C.

CLERK MAXWELL'S observation that a solid may be conceived to become fluid in three distinct ways suggests that, at a given temperature and pressure, all the different "degrees and kinds of solidity" may be characterised by three variables only. The object of the following investigation is to consider this possibility in the light of the mechanical tests now commonly employed by engineers and metallurgists. The tensile test shows that solidity involves at least three variables, so the question resolves itself into a search for evidence of a fourth.

It is well known that the usual mechanical tests are not of a very high order of accuracy. The yield-point," for example, has been defined by an authoritative committee, but can only be measured with precision when it happens to be sharply marked. Many metals break without "yielding," and metals which have a yield-point merge imperceptibly into those which have not. Observers naturally differ regarding the boundaries of the debatable zone, and within this zone the definition itself is sometimes compelled to yield a little. It would be tedious to recite the corresponding disadvantages of the other tests. In all of them the usual idea of "experimental error" must be greatly enlarged, and is better expressed as "experimental uncertainty." For the present purpose, therefore, engineering tests are only of value when a large number of experiments are available, and when there is no doubt that all of them have been executed in carefully standardised conditions.

Report of the Steel Research Committee.—The most satisfactory collection of figures, and indeed the only collection that is at all adequate, is contained in the Report of the Steel Research Committee, founded by the Institution of Automobile Engineers and the Society of Motor Manufacturers and Traders. This deals with 20 chemically different steels each subjected to a variety of heat treatments, thus giving some 200 different, or presumably different, solids. For most of these the yield-point, maximum stress, elongation, reduction of area, Brinell number, Izod number, and Charpy number were ascertained by three independent observers. Some 10,000 measurements are recorded in the report, but a considerable number of experiments were made which have not been published. For each of the 200 solids the committee give weighted mean figures representing their considered opinion, and these weighted means are the basis of the following analysis.

The committee present the results of their experiments in the form sanctioned by long usage, but it has been thought preferable to transform three of the measurements so that the representative figure shall bear a more recognisable relation to the phenomenon which it denotes. This, of course, is a detail of procedure which in no way affects the conclusions to be reached.

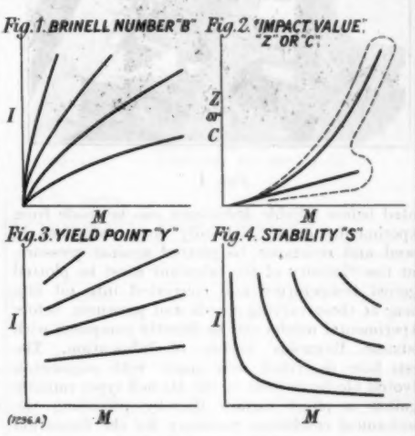
When a rod is stretched the load at any moment and the corresponding sectional area determine the longitudinal stress, and the sectional area itself determines the longitudinal strain at the section. A series of load-area measurements made in the course of a single test will thus give the co-ordinates of a longitudinal stress—longitudinal strain curve which relates wholly to the material and not partly to the test-piece. The report gives two points on, or nearly on, these curves, viz., the yield-point and a terminal point fixed by the reduced area and maximum load. The "maximum stress" and "percentage reduction of area" have therefore been considered in the form of "intrinsic strength" (*i.e.*, breaking load divided by broken area), and maximum longitudinal strain, which is given by the equation

$$\frac{dl}{l} = \frac{da}{a - da}.$$

This latter quantity conforms to the definition of what Maxwell has called "Mildness" and is therefore referred to under that name. Intrinsic length will be written I and mildness M.

The other quantity which has been re-computed is the "percentage elongation." When a rod is slightly overloaded the weakest part stretches first; it is thereby strengthened, but the reduction of area at the same time increases the stress; a race thus ensues between increase of stress and increase of resistance to stress. When the stress is leading the contraction goes on locally and abruptly, but when resistance to stress gets ahead the local contraction stops and other parts of the test-piece begin to suffer, *i.e.*, contraction spreads lengthwise. The property concerned may be regarded as the stability of the original (cylindrical) shape of the test-piece. "Percentage elongation" is open to objection as being the sum of two elongations due respectively to stability and to instability. The ratio of the longitudinal strain in 8 in. to the maximum longitudinal strain has been considered preferable, and (for present purposes only) is given the name "stability." Like "percentage elongation" this is an entirely unsatisfactory quantity, but it ranges between the easily recognised limits of zero and unity, and has been adopted because nothing better is available.

Method of Analysis.—The report gives seven properties of each body. The necessary and sufficient condition for the truth of the "three variables" theory is that for every body any three properties shall be represented by a determinate geometrical surface. If any fixed relationship



holds between properties A, B and C, and another fixed relationship between A, B and D, it is evidently possible to eliminate A and find a new fixed relationship between B, C and D.

The process of analysis consists in selecting two properties A and B as co-ordinates, and attempting to plot curves for a number of constant values of all the other properties. When the experimental information covers a wide range of each property, the inevitable experimental errors are unlikely to confuse the issue. Certain practical precautions however, are desirable. There is no *a priori* reason why curves, say, of constant C, should not intersect, but it is preferable that the independent variables should be chosen so that they do not intersect. In particular instances, it may be found that C does not depend on A and B, but depends on A alone, and, in such cases, it would be useless attempting to connect other properties with A and C. Yield-point is unsuitable as one of the independent variables because certain metals have no yield-point. On these and other grounds intrinsic strength and mildness have been chosen. It may be advisable to point out that the mechanical action in each of the experiments is far from simple, so it cannot be expected that the resulting curves will be expressible by any simple mathematical equation.

Brinell Tests.—Lines of constant Brinell hardness have the form shown in Fig. 1, the steeper curves corresponding to the higher Brinell numbers. At all points on the surface B appears to decrease with decreasing strength and with increasing mildness. When the strength is zero B is zero, and when M has a small fixed value B is approximately proportional to I. When M is very large a considerable strength gives only a small value of B.

We may notice in passing that the majority of the Brinell measurements were made with a load of 3,000 kg., but in some instances measurements with 3,000 kg. and with 2,000 kg. are given. According to the views expressed herein B_{3000} and B_{2000} will be represented by two surfaces which may be supposed to intersect along a single line defining a certain relation between I and M. For materials in which this relation does not hold B_{3000} will not be equal to B_{2000}.

Izod and Charpy Tests.—The report seems to establish that the only property indicated by these two tests is mildness, and as some doubt appears to have existed regarding the physical interpretation of "impact value" it may be useful to summarise the evidence. Some years ago it was shown experimentally that repeated Izod tests on the same material gave results falling, according to the accidents of uncontrollable experimental conditions, into two categories, viz., high results corresponding to gradual tearing, and low results corresponding to more or less complete snapping. The report confirms this for both Izod and Charpy tests, but over a considerable range of mildness the high and low values merge gradually, and are not clearly separated. These conditions are depicted in Fig. 2, which may be regarded as referring to either test; the drawn lines represent idealised high and low "impact values," Z or C, plotted on a base of mildness. The experiments are represented by points scattered all over the area bounded by the dotted line.

The Izod and Charpy tests are so similar that they must be supposed to give different measures of the same physical property, but materials T and U, say, which give the same Izod indication often give widely different Charpy indications, and *vice versâ*. When materials V and W give identical Izod numbers and also identical Charpy numbers it may reasonably be supposed that their "impact value" has been ascertained with some certainty, as the condition involves the concurrence of 36 independent measurements. A number of such pairs can be found in the report, and the mildness of both members is always the same although their other properties differ considerably.

The "uncertainty" of impact tests, even when they are carried out by experienced observers, has probably been overlooked because no standard was available for comparison. The Committee place a question mark against measurements which they consider to be unreliable and the relative frequency of question marks affords a rough gauge of the certainty of the several tests. On this basis the least reliable determinations are Izod number and Charpy number, with 8 per cent. and 5 per cent. of the experiments in doubt. The corresponding figure for the "percentage reduction of area" is 2½ per cent. A better estimate of errors can be made directly from individual figures as they appear in the report. The measurements of different observers cannot as a rule be compared because minor irregularities in heat treatment may have resulted in the metals being really different. There are many metals, however, which, within certain ranges, are almost unaffected by the degree of reheating temperature, and for these a comparison can be made between all the observations. It would be difficult to present the result in a fair light, and reference to the report itself is suggested. The fact that Izod and Charpy numbers agree somewhat better when plotted against each other than either does when plotted against mildness can no doubt be ascribed to elimination of independent errors in the measurement of M.

Yield-Point.—Curves of constant yield-point are of the form shown in Fig. 3, *i.e.*, they are fairly straight, and have a slope roughly proportional to the yield-point concerned. The lines begin at about M = 0·6, as less mild steels have no yield-point.

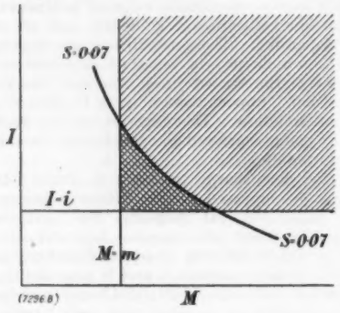
Stability.—Curves of constant stability have the form shown in Fig. 4. The axes constitute the locus for S = 1, *i.e.*, for zero mildness and for zero strength the stability is unity. An oblique straight line through the origin cuts curves of decreasing S successively. At any assigned mildness the lower stability gives the higher strength, and at any assigned strength it gives the higher mildness.

Deductions from the Steel Research Committee's Report.—The mechanical actions in the Steel Research Committee's tests include the slow breaking

of a round rod by tension, the breaking of notched rectangular bars by transverse blows at two different velocities, and the indentation of a plane surface by pressure from a more rigid body; the quantities selected as representative include energies, forces, lengths and pure numbers. It appears that all the representative quantities can be expressed in terms of three of them, and although the actions are somewhat diverse there is no indication of a fourth independent variable being concerned.

Lloyd's Tests.—Lloyd's rules governing steel for ship construction prescribe two experiments and three measurements. In the tensile test the "ultimate strength" must lie between stated upper and lower limits, and the elongation must exceed a lower limit; in the bend test a stated flexure must not involve tearing or cracking.

Fig. 5. LLOYD'S TESTS.



The "ultimate" or "maximum" strength U, intrinsic strength I and mildness M are connected by the equation

$$U = \frac{I}{M + 1}.$$

The bend test implies that M exceeds a certain figure m, but imposes no upper limit to M; Lloyd's tensile test therefore fixes a lower limit i to I, but there is no upper limit provided M can be correspondingly enlarged. The single hatching in Fig. 5 shows the unbounded zone of solidity which passes the ultimate strength and bend tests.

The percentage elongation in 8 in. E is related to stability S and mildness by the formula

$$S = \frac{E}{100\,M}.$$

Lloyd's require that E and M must individually exceed certain values, so S is not determined. We may suppose, however, that steel having a value of M which exceeds 3 is too costly for shipbuilding; E must exceed, say, 20 per cent., so S must exceed 0·07. The acceptable zone then becomes the closed triangle indicated by double hatching.

The bulk of the world's production of metals is required to pass tests equivalent to Lloyd's, *i.e.*, to undergo three measurements which have been shown to involve three independent qualities. Solids for shipbuilding and many other purposes are therefore sufficiently well defined when three variables have been specified.

Conclusions.—The tests which have been referred to involve separation and great deformation, and thus represent manufacture rather than use. A number of simple properties which are known to be of importance when metals are in service are not directly measured in any of the tests; they may be represented indirectly, or they may not.

On the whole it seems probable that solidity is a function of three variables only. Common observation shows that the various kinds of solidity are associated with very different strengths, so two variables may be supposed to determine the kind, and one the degree of solidity. Observation further suggests that at a given temperature and pressure solidity identical in kind and degree may be present in bodies of very different density. The object of testing is the right guidance of engineers, and the most convenient and economical experiments can scarcely be ascertained until the constitution of solidity is definitely known.

LUBRICATION TESTS.

By H. T. NEWBIGIN, A.M.I.C.E.

THE investigation of lubrication problems is complicated by the number of factors involved, each of which has to be isolated, and its influence noted before reliable deductions can be made from experimental data. Not only must variations in speed and resistance be plotted against pressure, but the viscosity of the lubricant must be plotted against temperature and converted into oil film shear at these varying speeds and pressures, before experimental results can be directly compared with Osborne Reynolds' theory of lubrication. The tests here described were made with segmental, pivoted blocks or pads, of the Michell type, running against a plane surface thereby providing the mechanical conditions necessary for the formation of true pressure oil films, and the load was applied while the bearing was running, thus eliminating any question of static friction. It was not possible to vary the speed with the apparatus used, this factor was therefore constant throughout the experiments, but variations in pressure, resistance, time, temperature and viscosity, were all recorded.

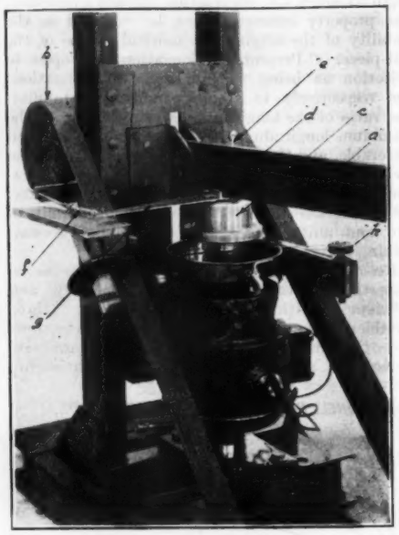


FIG. 1.

The apparatus consisted of an electric motor of 1 h.p. with spindle vertical. The bottom end of the spindle was carried in a Michell thrust bearing, and the top of the spindle was provided with a flat disc supporting a similar bearing upon which the observations were made.

In the photograph, Fig. 1, the letters indicate the parts as follows:—(*a*) Lever at the right-hand or outer end of which a scale pan is attached into which the weights were placed, the leverage being 10–1. (*b*) Balance weight which counteracts the weight of the lever and scale pan. (*c*) Oil container or cover in the form of an "ink well" into which a measured quantity of oil was placed. (*d*) Squared projection coming from the bearing tested and having two lips to loosely grip the lever and prevent the bearing from rotating. (*e*) Thermometer, the end of which is in the lubricant for reading the temperatures. (*g*) Torque arm by which the resistance of the bearing to turning was measured by the spring balance (*f*). (*h*) Small pulley driven by a cord from the spindle of the motor, from which the revolutions were counted.

The spindle of the motor acts as a strut and its strength limited the load which could be applied to about 3,000 lb., or 1,000 lb. per square inch on the pads. The pads and collars were finished by precision grinding so that when the pads were slid dry on to the collar the suction was sufficient to enable the collar to be lifted by its adhesion to the pads. The leading edges of the pads were rounded to about $\frac{1}{16}$ in. radius. Between the lever (*a*) and the projection (*d*) there is a steel ball resting upon a hardened steel face in order to eliminate as far as possible the friction between the lever and the bearing. As a further precaution the pull of the torque arm was measured in both directions, and the difference taken as being the actual pull. The details of the bearing tested are shown more clearly by Figs. 2 to 5.

Fig. 2.

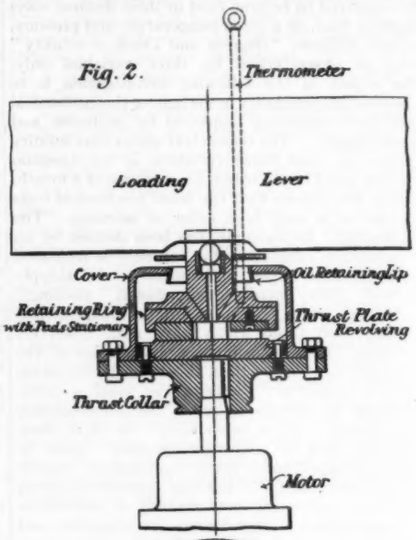
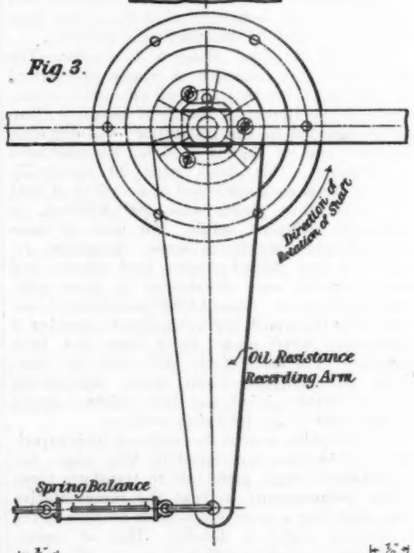


Fig. 3.



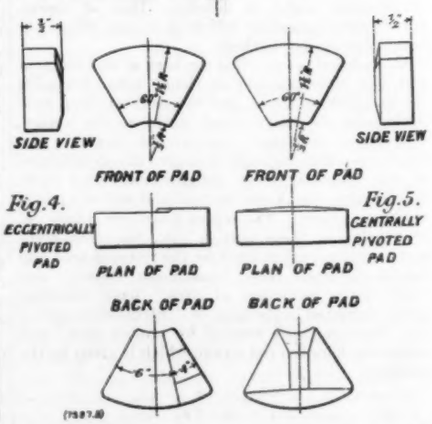


Fig. 4.

Fig. 5.

The viscosity curve of the lubricant used, shown by Fig. 6 on the opposite page, was plotted by means of a Michell viscometer (described in ENGINEERING, April 16, 1920, page 509).

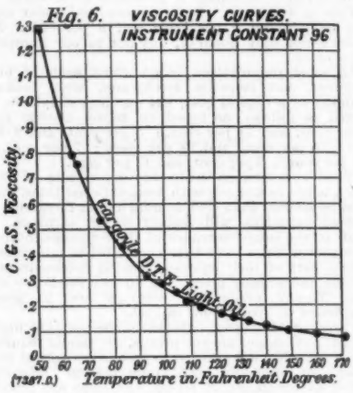
The tests were run, *inter alia*, to compare experi-

mental results with Osborne Reynolds' theory of lubrication. Tests were first run with pads pivoted behind their centre of area in the proportion of 0·6 to 0·4 as indicated by Michell, and the results are shown by the three lower curves in Fig. 7. The actual observation points being also given.

In Michell's paper on "The Lubrication of Plane Surfaces," *Zeitschrift für Mathematik und Physik*, vol. 50, pages 97 to 155, the following formulæ for a square block pivoted behind the centre as above, are given :—

$$c^2 = \frac{0{\cdot}0213\ \lambda\ u}{p} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (1)$$

$$\mu = c \times 10{\cdot}83 \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (2)$$



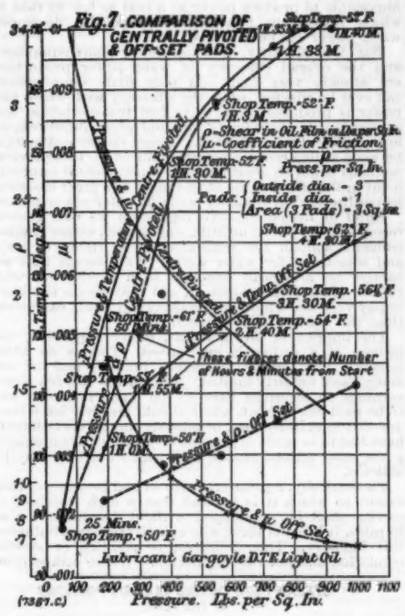


Fig. 7. COMPARISON OF CENTRALLY PIVOTED & OFF-SET PADS.
Shop Temp.-52° F.
1 H. 3 M.
Shop Temp.-57° F.
2 H. 30 M.
Shop Temp.-62° F.
4 H. 20 M.
Shop Temp.-56½° F.
3 H. 30 M.
Shop Temp.-54° F.
2 H. 40 M.
Shop Temp.-57° F.
1 H. 55 M.
Shop Temp.-50° F.
1 H. 0 M.
25 Mins.
Shop Temp.-50° F.
ρ-Shear in Oil Film in Lbs. per Sq. In.
μ-Coefficient of Friction.
Pads. (Outside dia. - 3 Inside dia. - 1 Area (3 Pads) - 3 Sq. In.
Pressure & Temp. Off Set.
Pressure & ρ. Off Set.
Pressure & μ. Off Set.
These figures denote Number of Hours & Minutes from Start
Lubricant Gargoyle D.T.E. Light Oil
Pressure. Lbs. per Sq. In.

LUBRICANT—GARGOYLE D.T.E. LIGHT.

Pads pivoted off the centre 0·6 from leading edge, and 0·4 from trailing edge.

Pressure in Lb. per Sq. In. P.	R.P.M.	Speed, Ft. per Second. V.	Temperature of Oil, —F°.	Viscosity, C.G.S.	Shear in Oil Film in Lb. per Sq. In.		μ = Coefficient of Friction.	
					Actual. ρ	Theoretical. R = 0·0332 √λPV	Actual. ρ/P	Theoretical. R/P
187	1,400	13·44	101	0·26	0·9	0·85	0·0048	0·0045
373	1,400	13·44	114	0·197	1·09	1·04	0·0029	0·0027
560	1,400	13·44	121	0·17	1·136	1·19	0·0020	0·0021
746	1,400	13·44	127	0·152	1·325	1·295	0·0017	0·0017
1,000	1,400	13·44	135	0·13	1·515	1·385	0·0015	0·0013

Where c = angle of inclination between the surfaces.
λ = the viscosity of the oil in C.G.S. units.
u = speed of rubbing in centimetres per second.
p = pressure in dynes per square centimetre.
μ = the coefficient of friction.

It has also been shown by Michell (Tran. Inst. Civil Engineers, vol. cxcvi, Part II, page 262), that the calculations for a segmental block having angular velocity are similar to those of a square block having a linear velocity.

In the author's paper on "The Science and Art of Lubrication," read before the Liverpool Engineering Society, 1919, formulæ (1) and (2) are converted into British units giving the formula :—

$$R = 0{\cdot}0332\sqrt{\lambda V P} \quad . \quad . \quad . \quad . \quad . \quad (3)$$

Where R = oil film resistance in pounds per square inch.
V = speed in feet per second.
P = pressure in pounds per square inch.

Let ρ = the observed resistance. Then tabulating the observed resistance ρ, for the offset pads, and the theoretical resistance R from formula (3), we get the following comparison between the experiment and theory. The values of λ are taken at the observed temperature from the viscosity curve, Fig. 6.

In the case of pads pivoted at or near the theoretically correct position it will be seen that the results obtained experimentally, given in columns 6 and 8, are in remarkably close agreement with those calculated from pure theory, given in columns 7 and 9, especially if allowance is made for slight errors of observation in the experimental results and the approximations made in the theory.

Tests were next made with centrally-pivoted pads, and the three upper curves in Fig. 7 show the results obtained, from which it will be seen that not only do the results no longer agree with theory but such pads are very much less efficient than those off-set. Furthermore, as the observation points do not lie in a fair curve, the pads would appear to be in a state of unstable equilibrium when so pivoted.

The author is indebted to Michell Bearings, Limited, for permission to publish these results.

ECONOMICS OF WATER-POWER DEVELOPMENT.*

By CURTIS A. MEES.

ECONOMICS as applied to this particular subject relates to the planning and administration of hydro-electric plants in such a manner as to avoid wastefulness and extravagance. The question of water-power development as a paying proposition, however, is another matter, and since each of these concepts covers a very wide field, it seems preferable at this time to touch, in a very general way only, on the essential factors pertaining to both problems in such a manner as to elicit profitable discussion thereon.

Only in very rare instances is it practicable to depend on water alone for the production of power for commercial purposes, and auxiliary power sources are therefore presumed to be a necessity, and their construction and operation is herein considered as concomitant to water-power development. The power business is akin to that of manufacture, as this term is usually conceived, and the conduct of this business is in many respects successful or unsuccessful in that measure in which the precepts for efficient and profitable manufacture are observed.

In other respects special problems are presented because the product after manufacture must be sold and delivered to the consumer, for instantaneous use in a circumscribed market; and while the selling cost is dependent entirely on the immediate operation of the law of supply and demand, the selling price is generally fixed by regulation. Just as this is true of any manufacturing enterprise, the success of a power development depends not alone on the perfection of the physical structure, *i.e.*, the mechanical equipment, and the production structure represented by the operating *personnel*, but in even greater measure on the efficient functioning of the commercial structure and the adequacy and flexibility of the financial structure. Many monumental developments are, by the well informed, known to be failures.

It should be readily appreciated, therefore, that in any abstract discussion such as this it is impracticable to attempt anything beyond merely setting forth various items that particularly require consideration in an analysis of the commercial features of a power development, and pointing out in general terms their effect on net earnings, or the margin between selling cost and selling price.

Factors of Selling Costs.—Selling cost is made up of raw material cost, fabrication cost and delivery cost. In each of these costs we have both variable elements subject to fluctuation with quantity production and susceptible to modification, and fixed elements which are not affected by applied economics, once the physical structure has been completed. To each of these classified accounts there must of course be disbursed, either directly or in proper proportion, managerial supervision, clerical expense, cost of tests and experimental research, and a multiplicity of similar charges which occur in all manufacturing business and involve no peculiar features. The raw material cost may be determined by any or all of the following items: Rental of water; land and water rights for reservoir; conditioning of reservoir; hydraulic control works; fuel delivered to plant; fuel-handling and storage facilities.

In establishing the feasibility of a development in view of these items, it should be noted that the unit cost of fuel is indeterminate unless quality is fixed by specification. The cost of fuel itself fluctuates with the market, generally in such a manner as to affect all competitors alike. Loss or deterioration in storage is a variable applying equally to fuel or water in a reservoir, and for water as well as fuel the unit cost is indeterminate unless quality and quantity are fixed by specification.

The cost of overflowed lands determines a fixed charge but the useful volume of water available and the effective head at which it may be used are variables, the proper determination of which constitutes the most difficult task involved in power-plant engineering and without the determination of which no unit is established for distribution of the cost.

Curiously enough, the requirements of purchasers of the product of this factory have a decided influence on the unit cost of the raw material, because while water may momentarily be available, its non-use at that particular moment may result in its utter loss. Prevention of such loss, to the greatest possible extent, is of course an extremely important consideration in the planning of details of the development.

The cost of structures such as dams, gates, pipe lines, coal crushers, oil tanks, &c., determines fixed charges for water or fuel. Operation and maintenance of these structures are variables, and in planning them the engineer may choose whether fixed charges or the variables shall be increased or decreased. For instance on the one hand a reservoir may be carefully cleared and the expense of so doing becomes a capital cost, or on the other hand only little clearing may be done and floating débris must then be removed from the racks from time to time. This expense then becomes an operating cost.

Fabrication Cost.—Of the three cost elements, fabrication is least affected by fortuitous circumstances. In a broad sense this cost is made up of fixed charges growing out of the capital cost of erected power-generating equipment, suitably provided with necessary or desirable adjuncts, housed or located outdoors as the case might be, and of operating charges which include wages, supplies, repair parts, &c. Capital cost of the plant may, however, and quite properly so, lie between wide limits for the same output of product, depending on two totally distinct provisions: uniformity of stream flow and character of service requirements, both as to continuity and uniformity.

It must be borne in mind that the manufactured product is kilowatt-hours, that the time element is just as important as the capacity element and that, in general, a sale is consummated only when capacity is available at the instant of use and for the period of use. Thus the hours of use for any given market must be most carefully predetermined for the proper selection of prime movers, and beyond this capacity must also be provided equivalent to the maximum instantaneous demand for current, else the product will not be saleable.

It is readily apparent, therefore, that in general only one-half as much generating equipment is necessary for a 24-hour load as for a 12-hour load, and that for a 24-hour load only one-half as much equipment is required to produce a perfectly uniform output as for a demand which fluctuates from zero to double the average load.

Capacity for the water-power plant having been fixed by the character of the load, there follows the determination of proper capacity for the auxiliary plant. While this choice may possibly be dependent on a volume of output imperatively continuous, it is much more likely that it will hinge on meteorological criteria. One need only to mention that, in the first place, the run-off from any drainage area or the discharge of a stream fluctuates between very small quantities at times of drought and quantities sometimes many thousand times greater when in flood with, in general, little regularity about the occurrence of either stage, and that, in the second place, the average usable discharge for some years is considerably lower than for others.

Natural stream flow is determined either by measured discharge or by computed run-off based on recorded rainfall. From these data there is estimated the average annual stream flow, and these determinations will approach correct values according to the length of the period of observations considered. These findings should be modified by an accuracy factor.

Depending on the topography of the development site, either at the power plant or on the drainage area above

* Presented at the spring meeting, Atlanta, Ga., May 8 to 11, 1922, of the American Society of Mechanical Engineers.

it, storage capacity may be created of such extent as to afford either daily or seasonal regulation. By daily or weekly regulation is meant the conservation of natural stream flow during 24 hours or 7 days for use during those hours only when load can be sold. By seasonal regulation is meant the controlled, artificial increase of natural stream flow out of waters stored during periods of run-off in excess of the usual quantity.

Regulated stream flow having been ascertained for each year and for the average of all years of record, it will be found that, when daily discharges are plotted as shown in the diagram reproduced herewith, one can very readily forecast what power output is continuous and what additional output may be sold for any predetermined portion of the year, as this is fixed by low-water stages.

For high-water stages, while there will be an excess of water available, it frequently happens that loss of head results from this cause, and in that event restriction of output must be determined similarly as for low-water stages. Only in exceptional cases is it commercially practicable to develop a water power plant for an output based on an absolute minimum stream flow, and it is therefore customary to base earnings on that output which may be produced in the average year.

The equipment of the auxiliary plant is then primarily fixed by that capacity which may be necessary to supplement the water output of the lowest year to bring it up to that of the average year. Beyond this, except for possible emergency capacity, it becomes a question of dollars and cents, based on saleability of secondary power and rates which may be secured for this service, as to the extent to which one can afford to install auxiliary equipment for the conversion of short-term water output into continuous combined water and auxiliary output.

Dependent on local conditions, the capacity which must be installed for emergency service might finally be the determining factor in equipment selection. It may happen that in flood a water-power plant may be completely incapacitated through loss of head so great as to make impossible the maintenance of synchronous speed. Ice blocks also might completely prevent operation of a plant. For such cases, under certain load conditions, it might become imperative to provide 100 per cent. stand-by capacity.

Legitimate capital cost and resulting fixed charges must therefore be most carefully determined for each individual project and comparative figures are not necessarily indicative of their propriety. Another so-called fixed charge is quite beyond control, and that is taxes. Cost of supplies and repair parts are regulated by the law of supply and demand, and cost of labour may, or may not, be determined similarly according to the extent to which organised labour can enforce its dicta as to rules and rates.

One phase of control as to fabrication cost is of particular importance in this business and that is the continuous, most efficient conversion of raw material into the finished product. This is not a question of workmanship but rather one of intelligent direction. Loss in kilowatt-hours produced out of available water and per unit of fuel may, under proper allocation of part loads to various equipment items, be considerable and difficult of detection.

Delivery Cost.—Delivery of power may be effected either direct to the ultimate consumer or at wholesale to a distributor and the cost of delivery depends very largely on the method in vogue or proposed, but the greater cost of retail service is offset by a rate differential such that in the end earnings on the unit of investment are not, in general, materially affected by the adoption of one rather than the other of these plans.

A transmission system may be considered to be composed of trunk lines, secondary lines and feeders. The cost of trunk lines depends primarily on the proximity of the power plants, principal and auxiliary, to each other and to the centre of load, whereas the cost of secondary lines and feeders depends largely on quantity requirements, both as to capacity and period of use, or what is synonymous, the number of consumers served and the density of the market.

Secondarily the cost of transmission lines is affected by the relative importance of assured continuity of service and in addition the locality variable enters into the problem. Urban work, values of land, size of properties crossed and similar circumstances greatly affect the cost of lines. The rigors of climate, cyclones and the prevalence of electrical disturbance, require careful consideration, and arbitrary regulations as to structural details must frequently be observed whether the cost is justified or not.

Conductor cost should be balanced for permissible line loss at prevailing rates, and transformers, to prevent excessive core losses, should be so proportioned as to carry capacity loading as much as possible.

Fixed charges for distribution plant, based on right-of-way costs, leases or fees and equipment and structures costs, may therefore also vary between very wide limits with perfect propriety.

Operating costs of the system depend on topography, multiplicity of lines, substations and terminals and their accessibility by rail or highway, weather conditions and special maintenance requirements for city lines, stream or railroad crossings.

Factors of Selling Price.—Selling price depends on either the cost of a competitive product or rates fixed by a regulatory body; i.e., in the last analysis, by the purchaser. The competitive product may be either purchased electrical power or produced power. Regarding the practicability of competition with purchased power, there can of course be no controversy. However, the feasibility of building a water-power plant or system for the competitive sale of electricity with that otherwise produced is not always so readily established. The selling cost of high load-factor power, produced in large volumes with fuel at reasonable cost is not, in general, appreciably higher than that produced by water, if in the latter case the transmission cost amounts to much.

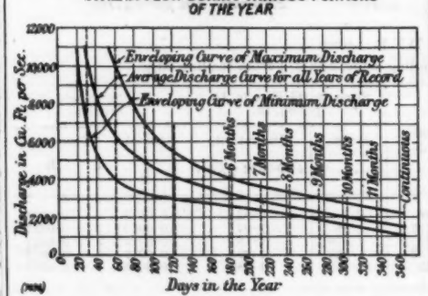
In small fuel plants, however, and particularly when operating at a low load factor, it is at the present time impossible to produce power at a cost as low as that at which reasonably near and economically developed water power can be delivered.

But the efficiency of water-power plant equipment and the overall efficiency of water-power production are already very high and only little improvement can ever be effected, while the efficiency with which fuel power is produced, both as to fuel transportation and conversion, is exceedingly low and great improvement may confidently be expected. Hence the present margin between selling costs of power produced by these several methods is not so great but that a pronounced improvement in the effective use of fuel may, in a great measure, jeopardise the investments made in water-power plants.

Effect of Regulation.—To regulation we owe general recognition as public utilities, and as such we are granted eminent domain for transmission-line rights of way, and sometimes for water rights. This means that we cannot be arbitrarily stopped from proceeding with certain plans of development, and that we do not have to pay very much more for property rights and easements than the market value thereof.

The impression prevails that, under regulation, the income of a utility is guaranteed. This is an utter fallacy. The income is merely limited, and in too many cases unfairly limited. Within the last few years earnings on securities have in too many instances had to be paid out of funds which should properly have been devoted to maintenance, or possibly unwise curtailments have had to be made in *personnel*. Deferred maintenance is the most serious disease with which a utility may be afflicted.

Theoretically, regulation is not so bad because, to that extent to which it is insisted that a high standard of service shall be maintained without discrimination as to rates, it benefits those who conscientiously administer this industry. This, however, is practice or service regulation and not rate regulation. Where competition



is free, economic law operates to prevent continued exorbitant profit-taking, the art is developed, and progress is made. Particularly with the power industry would this be the case.

Bearing on this question, the following issues are important: Permitted rates of return on investment are inadequate; certain other irretrievable losses of income may not be covered by rates; certain non-insurable risks may not be offset out of rates; unfair competition is not throttled; efficiency receives no reward.

A public utility that is not constantly expanding is decadent. New money must at frequent intervals be secured to finance extensions required from time to time, oftentimes under instructions of the commissioners.

In principle the returns on investment permitted under regulation are intended to be sufficient only for payment of interest and dividend, and for the perpetuation of the investment out of a depreciation reserve. The establishment of a sinking fund, out of earnings, is not proposed and borrowed money must therefore be kept in perpetuity.

It is of course both logical and proper that the depreciation reserve fund should be reinvested in the property to cover cost of extensions, but this money should in the first place, under healthy growth, be inadequate, and furthermore, once so invested the resources of the corporation become so non-liquid as to expose the administration to considerable financial embarrassment in cases of emergency when immediate funds should be available. At such times the desperate need for money is naturally and not without warrant taken advantage of because credit has been impaired.

Composition of Financial Structure.—The financial structure which supports this industry is, in general, composed of:—

A Lender: To whom payment of interest is compulsory under the security which he holds and which amounts to the entire property owned.

The lender sees to it that this is a safe risk. His criterion generally is that estimated net earnings shall be at least two times and generally two and one-half times the bond interest.

A Preferred Investor: In stock whose payment in dividends is substantially guaranteed under a lien subordinate only to the bondholders' equity. This investment is attended with all sorts of management and non-insurable structural risks.

A Speculative Investor: In common stock whose dividends are paid only if there is anything left over.

Customary and proper rates of return under respective security holdings may be set up as follows, based on the existing actual, not legal, interest rate for short-term collateral loans of equal volume:—

	Per Cent.				
Actual interest rate ...	4	5	6	7	8
Bond interest	5	6	7	8	9
Preferred stock dividend	7	8	9	10	11
Common stock dividend	10	11½	13	14½	16

One court held that the average rate of return on the entire investment should be 3 per cent. above the existing interest rate.

The actual rate of return on capital ordinarily invested in any business enterprise is oftentimes lost sight of because it is confounded with the percentage of net profits made on units of output. If a turnover can be made four times in a year and a net profit of 6 per cent. is made each time on the goods sold, the actual rate of return is 24 per cent. and not 6 per cent. This is not at all an extraordinary performance. A power plant is exceedingly fortunate if it makes a turnover once in four or five years. Returns permitted under regulation lie between 6 per cent. and 8 per cent. Some commissions may possibly, but not to our knowledge, allow more.

An ideal organisation is one-third each of bonds, preferred and common stock and, with brokerage included as a capital cost, net earnings should be permitted as follows, as based on actual interest rates: 4 per cent. and 7½ per cent.; 5 per cent. and 8·5 per cent.; 6 per cent. and 9¾ per cent.; 7 per cent. and 10⅞ per cent.; 8 per cent. and 12 per cent.

When commissions arbitrarily fix a rate of return which is not in keeping with financial conditions, money must be secured from such sources and at rates such that interest payments will remain within earnings. The result of the non-observance of these fundamentals has been that utilities have been compelled to mortgage too large a part of their equities, bonded indebtedness has become dangerously great, and no new funds are available. To-day permissible earnings are, in general, insufficient to attract new capital.

Unrecoverable Losses.—Based on the law that utilities should not make unjust profits, it should equitably follow that they are entitled to protection against unjust losses. In financing such undertakings reliance is placed on constancy of return and rates are predicted on probable normal output. Industrial activity, however, varies in cycles and a falling-off of normal business cuts into earnings in a manner which cannot be guarded against because, in general, equipment capacity kept in readiness to serve under contract provisions cannot be otherwise put to work. Contract minima, ordinarily assure nothing more than the earning of bond interest alone.

Losses of output, and therefore earnings, are sometimes seriously affected by storm or flood conditions, against which the property cannot be guarded. Fire and breakdowns may, without fault on the part of the operating *personnel*, render normal service impossible, and emergency service under any of these conditions is apt to be very expensive, but nevertheless practically obligatory. Interference with business by strikes, declaration of martial law, &c., mean unavoidable loss of income.

Against none of these contingencies can the management protect itself as this is customarily done and essential to safe business conduct, *i.e.*, by the setting aside of a contingency or, as it has been called, a "stabilisation" fund.

As to water power particularly, a development condition prevails which must be taken into account. The cost of prime movers is almost invariably only a small percentage of the total cost of all structures which must be completed in order to be able to manufacture any power whatever, and the progressive development of the plant to meet the growing requirements of the market is more or less impracticable. Over-development, therefore, is the rule, and since, for purposes of rate-fixing, earnings are predicated on possible output instead of on probable demand, certain losses of income occur during the period required to bring sales up to the developed output capacity.

Under these unalterable circumstances the loss of earnings which are necessary to offset interest and dividend payments and the setting aside of funds to cover a depreciation which is actually going on, may legitimately be treated as development costs, either to be included in the capital cost on which the rate of return is based, or otherwise covered in the rate composition. One court, however, has held that any compensation for business losses in the adjustment of rates leads to a *reductio ad absurdum*.

Quite enormous losses have been incurred by power companies due to great delay in the granting of those higher rates which the commissions by their own rulings have established as having been justified. Such requests of course grew very largely out of increased operating costs and to that extent to which they represent operating costs only and not the earnings of capital invested during the period of high prices, a future reduction in rates is to be expected. It remains to be seen whether it will be permitted that losses already sustained can be recouped before reductions in rates are ordered. Floods may destroy dams and cause tremendous damage to persons and property. Lightning may burn up transformers and other equipment. Falling trees, wind or sleet storms may cut transmission lines in two and by short-circuit magnify the direct damage. Death-dealing currents take their toll of life regardless of even extraordinary precautions and, while such a risk is insurable, the amounts involved are limited and in any event defence in litigation is very costly.

Premature destruction of structures and equipment is not covered by the depreciation reserve and accidents requiring the outlay of additional capital without a corresponding increase in earning capacity can be

covered only by a contingency reserve, provision for the accumulation of which should be included in the rate structure.

The antiquation or obsolescence of parts or even the whole of the plant through the possible development of novel equipment or methods for power production at lower selling cost than that possible with equipment now available or even by water power at all, is not too remote a happening to be given consideration, and this contingency should, in a measure at least, be offset by liberal present earnings.

That efficient operation of public utilities promotes the welfare and growth of any community is obvious. If, therefore, the regulatory bodies would take a proper pride in the efficiency of the utilities which they regulate and would do everything to make it possible for the companies to deliver on sound financial bases the best service at the lowest rate, they would be doing their communities a signal service. Also in order to allay much of the antagonism toward public utilities fostered by political attacks, regulatory bodies should demand of all utilities under their jurisdiction, including the municipal plants, a uniform system of accounting such as to expose many of the fallacies now entertained.

Rates for electrical current are presumably based on cost of the service, painstakingly predetermined for each particular case. Cost of service is, however, susceptible to considerable modification depending on the degree of efficiency attained in administration of the property. If earnings are absolutely limited, the incentive to efficiency is lost and that is one of the most discouraging features of rate regulation. Zealous communism is only a theory.

It must be remembered that small plants require different treatment from that accorded to big plants and that isolated plants must be quite differently planned from those forming part of a chain or system.

In the light of what has gone before the question as to whether water-power development is a paying proposition may now more intelligently be answered.

Water-power development does pay—never big, however, but even very small plants of high unit cost entirely justify their existence. It does not pay at this time because the public will not invest in securities at interest or dividend rates which permit the financing of such undertakings on a basis of present permissible earnings. However, these facts notwithstanding, it is a gloriously constructive work and, because of the individuality of each project and the ever present hazard, it certainly may be ranked as the greatest sport on earth.

THE PENFLEX RIVET "GUN."—The Penflex rivet "gun," of the Pennsylvania Flexible Metallic Tubing Company, Philadelphia, in use at the yard of the New York Shipbuilding Company, is illustrated in the *Iron Age*, for August 17. The "gun" and the forge are conveniently located at a distance, tubing leading to the job. As each rivet is heated and ready to be passed, it is set on a valve provided in an opening contained in the head of the "gun." The rivet opens the valve by its own weight and enters the machine. The valve closes then automatically and the rivet is sent on its journey simply by pressing a foot treadle, this placing the "gun" in communication with a compressed air receiver. The rivet "gun" has a distance capacity of 125 ft., delivering rivets up or down at the rate of 50 ft. every 3 seconds. It is claimed that the "gun" has exceeded this performance, shooting rivets 180 ft. in 9 and a fraction seconds without subjecting the rivets to change of temperature. One of its outstanding advantages is that it eliminates the necessity of placing rivet forges in close compartments near the riveting work in hand.

FOURTH INTERNATIONAL ROAD CONGRESS, SEVILLE, 1923.—The following schedule issued by the Ministry of Transport shows the range of the subjects to be discussed at the Fourth International Road Congress which will meet at Seville in May of next year by the invitation of the Spanish Government.—*First Section—Construction and Maintenance*:—First Question—Surfacing of roads with concrete: A. Dryland, M.Inst.C.E., County Engineer of the Middlesex County Council. Second Question—Use of bitumen and asphalt for surfacing. (The use of tar and its derivatives is not comprised in this subject). In collaboration: J. S. Killick, C.B.E., M.Inst.C.E., late Chief Engineer of the Roads Department, Ministry of Transport; and T. S. Marriot, Limmer and Trinidad Lake Asphalt Company. Third Question—Laying tramway-rails on the various kinds of road surface: John A. Brodie, M.Inst.C.E., City Engineer, Liverpool. Communication—Progress made in modern mechanical appliances used in the Construction and maintenance of Roads: Further improvements and new machinery introduced since the last Congress (London, 1913). In collaboration: A. E. Brookes, O.B.E., County Surveyor of the Durham County Council; and A. E. Collins, M.Inst.C.E., City Engineer, Norwich. *Second Section—Traffic and Development*:—Fourth Question—The development of Motor transport: F. Pick, London Underground Railways. Fifth Question—General Traffic Regulations. In collaboration: E. Shrapnell-Smith, C.B.E., President of the Commercial Motor User's Association; and J. S. Pool-Godsell, Ministry of Transport. Sixth Question—The problem of traffic on congested roads and streets of towns. In collaboration: W. Rees Jeffreys, Road Improvement Association; and A. E. Cave, Motor Legislation Committee. Against each subject or "question" appears the name of the expert selected to voice Great Britain's views and to present a report for consideration by the Congress; every aspect of modern road and traffic problems will be adequately and authoritatively reviewed.

EXPLOSION OF A CORNISH BOILER.

A PRELIMINARY inquiry has been made by the Board of Trade under the Boiler Explosions Acts, 1882 and 1890, with regard to the cause and circumstances of an explosion of a boiler which occurred on December 13 last at the works of the Staveley Gas Light and Coke Company, Limited, Staveley, near Chesterfield. Fortunately, no one was killed or injured by the explosion.

The boiler was of the Cornish type, 12 ft. 2½ in. in length by 4 ft. 9 in. in diameter. The shell was built of four rings of plating, with two plates in each ring, and both the longitudinal and circumferential seams were lap jointed and single riveted. The plates, as far as could be judged, appeared to have been ⅜ in. thick originally, and the rivets ¾ in. in diameter, and $1\frac{15}{16}$ in. pitch. The end plates were connected to the shell by means of angle bars, and there were three gusset plates at each end, above the furnace tube, staying the ends to the shell. The furnace tube appeared to have been made of iron, and was built of five rings with lapped seams, and each ring had one lap single-riveted seam, these being placed alternately at the opposite ends of diagonal diameters, with the exception of the front ring seam, which was on the opposite side of the furnace to that of No. 2 ring, but was at the same level. The furnace tube was 2 ft. 6½ in. in external diameter at the front end, and 2 ft. 5½ in. at the back and was attached to the end plates by angle bars. The furnace plating appeared to have been originally ⅜ in. thick and the rivets were of the same diameter and pitch as those in the shell. The boiler worked under natural draught.

At the time of the explosion, the following mountings were fitted:—

One open-type lever safety valve.

One water-gauge, 9½ in. in length.

One pressure gauge, graduated to 120 lb. per square inch.

One injector.

One blow-down cock.

One steam stop-valve, not connected directly to the shell, but situated in the steam line at a distance of about 2 ft. from the pipe attachment to the boiler.

The boiler was supplied by Messrs. Parker and Marney, Limited, machinery brokers, Sheffield. The exact date was unknown, but was said to be about 20 years ago. It was then second-hand, and the name of the maker could not be ascertained at the time of the purchase. No repairs had been done to the boiler since it was acquired by the present owners, with the exception of replacing the fusible plug with a new one, the position being in the furnace-crown at a distance of about 3 ft. 9 in. from the front end.

The boiler was insured with the United Legal Indemnity Insurance Society, Limited, 222-225, Strand, London, and was periodically examined by their inspectors, the last inspection being made by Mr. H. S. Spittle, on April 20, 1921.

In his report, Mr. Charles Harvey, Engineer Surveyor to the Board of Trade, states that the boiler of which the explosion occurred was known as No. 1, and was one of the two Cornish boilers in alternate use for supplying steam to the water-gas plant, and also for exhausting the gas from the retorts by means of a Korting ejector, in the production of coal gas.

An open-topped tank, 6 ft. by 3 ft. 2 in. by 3 ft. 6 in., from which the boiler feed water was taken, was situated in the boiler house near the front end and at the level of the top of No. 1 boiler, and was supplied with water from two sources, viz., the town mains by means of a ¾-in. bore pipe, and the Chesterfield and Stockwith Canal, from which latter source an injector delivered water through a ¾-in. bore pipe in to the top of the tank. A ball float arrangement, in the tank, automatically controlled the admission of the water from the town supply. A 1¼-in. bore pipe, connected to the end of the tank at about 3 in. from the bottom, conveyed the feed water to the boiler injector, which was placed near the front end of the boiler.

On the occasion of the last inspection of No. 1 boiler, the inspector to the insurance company, not being fully satisfied with the general appearance of the shell, reduced the permissible working pressure from 60 lb. to 40 lb. per square inch, and stated on his certificate that at the expiration of the ensuing six months it would be necessary to drill the shell plating in order to ascertain its thickness, and to subject the boiler to a suitable hydraulic pressure. In the event of the thickness and the subsequent hydraulic test being satisfactory, the higher pressure would probably have been assigned again, and, for that reason, the inspector stated, he did not shorten the safety valve lever or adopt any other measures to reduce the load on the valve to accord with the lowered working pressure of the boiler. He stated, however, that he instructed the late manager, Mr. Ford, to adjust the ball on the lever so that the steam would blow off freely at a pressure of 40 lb. per square inch. This statement was supported by Mr. George Belsey, boiler attendant, who in his evidence stated that he was instructed by Mr. Ford to work the boiler at 40 lb. pressure.

On November 11 last, when the boiler was under steam, the inspector adjusted the ball to a position which allowed the steam to blow off at 35 lb. pressure, but, Mr. Harvey reports, when he visited the works after the explosion, the ball was at the extreme end of the lever, and as no one appeared to have deliberately moved the ball, it was probable, there being no provision for securing the weight in position, that it moved to the end under the influence of vibration.

According to the evidence, the pressure showing on the gauge just prior to the explosion did not exceed 40 lb. The pressure gauge was checked against one of the Board's standard gauges, and it was found to register 6 lb. in excess of the correct pressure, so that the actual pressure in the boiler would be 34 lb. per square inch. For some time previously there had been difficulty in maintaining an adequate quantity of water in the feed tank; the injector in the pipe line from the canal had been out of order and the only available supply—by means of the ¾-in. pipe—was insufficient to meet the demands of the boiler.

On December 13 last, the day of the explosion, Belsey, being on the 2 p.m. to 10 p.m. shift, came on duty at 2 p.m. and verified the reading of the water-gauge, and was satisfied that everything was in order; 4 in. of water was showing in the glass and 40 lb. on the pressure gauge. He continued to inject water into the boiler from time to time, keeping the injector at work until the supply from the tank was exhausted, but the water level in the boiler steadily got lower.

The following particulars were given in evidence:—

At 7 p.m. there was ¾-in. of water showing in the glass, and as the feed tank was empty, the stop valve was closed and the fire withdrawn, Mr. Irvine Marsden, the working manager, being present. A few minutes before 9.0 p.m., when a good supply of water had accumulated in the tank, the fire was relighted. In the meantime, the steam pressure had fallen from 40 lb. to 35 lb., and, according to the evidence of Mr. Marsden, the water level in the boiler was below the bottom of the glass, but could be seen "in the nut" by looking from above. By 9.30 p.m. the steam had risen to 40 lb. pressure and the injector was then started and kept going until the time of the explosion, about 9.45 p.m., when there was a ¼ in. of water showing in the glass.

It was said that the injector did not work efficiently at pressures less than 40 lb. per square inch, otherwise it would have been started on relighting the fire at 9 p.m.

The furnace tube collapsed over a length of about 6 ft., between Nos. 2 and 4 ring seams, the maximum depression being at No. 3 seam, at which place the plate tore by way of the rivet holes, leaving, roughly, a diamond-shaped opening about 1 ft. 11 in. by 2 ft. 4 in., almost the full diameter of the furnace. The crown at this part was forced down to within 4 in. of the bottom. The contents of the boiler were discharged through the opening, wrecking the brickwork of the flue at the back of the boiler.

Mr. Harvey, continuing his report, states on examination after the explosion, the furnace was found to be slightly corroded on the fire-side in the form of smooth wasting, and somewhat badly pitted on the water-side, so that the effective thickness was not more than $\frac{5}{16}$ in. The fusible plug was removed and examined, and it would appear that when the outer portion or casing of the plug was screwed into its seating, the screwed part had suffered some slight distortion, being slightly closed in, which defect, as was proved on the occurrence of the explosion when all the fusible material had melted, prevented the plug being discharged, thus rendering the fitting useless.

The boiler was in fairly clean condition internally, and the overheating of the furnace, which undoubtedly took place, was due to shortness of water, thus causing the explosion of the furnace tube, which was subjected to a greater pressure than it could withstand.

In his "Observations," Mr. Thomas Carlton, Engineer Surveyor-in-Chief to the Board of Trade, sums up as follows:—"The damage to property and risk to life which may arise from shortage of water in a boiler are so serious, that it should be observed as a general principle that where the feeding of a boiler depends upon the operation of a mechanical appliance, an alternative method should always be available for use in the event of the failure of the pump, or other appliance ordinarily in use. In the present case the supply of feed water from the town mains was restricted and could only be regarded as supplementing, the chief supply obtained from a canal by means of an injector, and it was insufficient to make up the shortage occasioned by the defective condition of the injector. It was due to the imperfect feed arrangements that those in charge were led to take the risks which brought about the explosion in the manner described, and altogether, as shown not only by the feed arrangements but also by the dangerous pressure to which the safety valve was found to be set, there appears to have been laxity in the supervision and working of the boiler.

"A noteworthy circumstance which deserves attention," Mr. Carlton adds, "was the failure to function of the fusible plug through the closing in of the orifice, presumably when the plug was screwed home in the plate."

THE ASSOCIATION OF ENGINEERS-IN-CHARGE.—We learn that Professor H. S. Hele-Shaw, D.Sc., LL.D., F.R.S., has consented to succeed Capt. H. Riall Sankey, C.B., C.B.E., R.E. (retired), as President of the Association of Engineers-in-Charge for the 1922–23 session. This is the second time Dr. Hele-Shaw has been President of the Association, as he occupied the Chair in 1912–13. The Presidential Address will be delivered in October.

THE LATE MR. FRANK BURR SMITH.—We regret to have received information of the death, which occurred on August 16, of Mr. Frank Burr Smith, of Cherry street, Milford (Connecticut), works manager of the Bullard Machine Tool Company, Bridgeport (Conn.). Mr. Smith was born at Mohican Springs Farm, Fairfield (Conn.), on November 22, 1872, and entered the Bullard Company as a machinist apprentice in 189⁰. He then held positions in several other concerns, returning finally to the Bullard Company in 1911, whom he represented in a sales capacity, with headquarters successively in Chicago, Cleveland and Philadelphia. The last year of his sales work was spent in England and was coincident with the first year of the war. Shortly after his return to the United States he was appointed works manager of the company, a position he occupied until his death.

ROAD-BREAKING AND TAMPING MACHINE.

THE machine illustrated on this page represents a large example of the machinery constructed by Messrs. B. Johnson and Son of Bramley, Leeds, for the breaking up of concrete or macadam roads or the tamping of earth in refilled trenches. It consists essentially of a steel frame on wheels, superimposed on which is a long swivelling lever. At the front end of the lever are a pair of shafts geared together, and carrying smooth-faced pulleys, the rims of which are partly cut away. Between the pulleys is an ash plank running in vertical guides, and provided at its lower end with a breaking head, or tamping head as the case may be. One of the pulley-shafts is spring mounted, so that the plank is nipped between the pulley rims. The pulley-shafts are driven by means of a belt from an oil-engine at the back end of the swinging lever. As they rotate, they lift the plank, which drops freely again as soon as the clearance part of the pulley rims comes round. A brake permits the plank to be arrested in any position. The operator at the rear end of the machine can swing the lever from one side to the other as the work proceeds, so that a considerable width of ground may be acted upon.

As shewn in the illustration, the machine is engaged upon the breaking up of a macadam road, previous to the excavation of a trench, the work being carried out by Messrs. W. G. Tarrant, Limited, of Byfleet, in connection with their Wandle Valley sewer contract. It will break up from 130 sq. ft. to 175 sq. ft. of macadam per hour, the material being 6 in. thick. The weight of the ram is 250 lb., and it strikes about 55 blows per minute, the length of the drop being 2 ft. The swivelling portion is long enough to permit the machine to work over a maximum width of 12 ft. In cases where it cannot stand astride the job, such as in tamping a trench alongside, the machine has, of course, to do its work on one side of the frame only, and under such conditions trenches up to 4 ft. wide can be tamped. On the contract to which we have referred, the machine illustrated will be required to tamp the re-fill of a trench 11 ft. 6 in. wide. The total weight of the machine is 32 cwt. Machines of this type have been found very satisfactory in use, the work being expedited and the labour cost substantially reduced.

THE RALEIGH MOTOR BICYCLE.

THE modern motor bicycle has arrived at a degree of reliability and efficiency which is really remarkable considering the difficulty of the problems which are involved in its design. It owes its development much more to the dictates of experience than to any theoretical guidance, and its design hardly came under the serious consideration of engineers until the magnitude of the demand directed attention to the manufacturing aspect of the question. To meet the demand for a motor cycle which would not only have the reliability, safety and handiness that the average unskilled rider requires but which at the same time could be put on the market at a reasonable price, the Raleigh Cycle Company of Lenton near Nottingham have developed the machine illustrated in perspective Fig. 1 on the opposite page, while several important details are shown in sectional drawings (Figs. 2 to 11). This machine they are now manufacturing on a very large scale and by taking advantage of all the facilities which quantity production makes possible, it can be sold at a figure which is eminently reasonable considering its quality and the the completeness of its equipment. The company also manufacture a larger and more powerful machine for heavy side car work, but the one we illustrate is adequate for all the requirements of the average rider.

The machine with which we are dealing is rated at 2·75 h.p., but the rating of British motor cycle engines is somewhat anomalous as is seen by the fact that this particular engine regularly develops about 6·5 b.h.p. at 3,000 r.p.m., when tested, as every engine is, by means of a Froude dynamometer at the works of the company. This is a consideration which should be borne in mind when comparison is made between British and imported machines. The motive underlying the whole design is to provide a sound and serviceable motor cycle to come within the 350 c.c. class and also under the 200 lb. tax limit. Many of the detail parts are equal in strength to those ordinarily employed on machines of considerably greater horse-power, notably the wheel hubs, ball-head, engine-bearings, rear-brake, &c. A ¾-in. belt is also fitted for the final drive. The frame, moreover, is of very strong construction and quite capable of withstanding the strains due to the attachment of a side-car. In this connection it may be stated that clips are used for such attachment instead of solid lugs, as this makes possible a considerable saving in weight. The rear and front hubs are built of interchangeable parts except as regards the central barrel portions and the spindles. Steel stampings are used in preference to

ROAD-BREAKING AND TAMPING MACHINE.

CONSTRUCTED BY MESSRS. B. JOHNSON AND SON, BRAMLEY, LEEDS.

malleable castings in all important parts of the machine. The petrol tank is made of two pressings welded together, and as the bottom of it is seamless the risks of leakage are reduced to a minimum.

The engine, illustrated in Figs. 2 to 4, is of the four-stroke type with mechanically operated valves, in contradistinction to the two-stroke valveless engines which are frequently fitted to the less expensive makes of motor cycle. The cylinder bore is 71 mm. and the stroke 88 mm., giving a cylinder capacity of 348 c.c. Plain bearings are used throughout the engine. An outside flywheel is employed, as this permits of much greater flywheel-effect for the same weight. The flywheel is dished so as to allow of the main bearing being carried out until it is situated as favourably as possible to resist the pull of the driving chain, the overhang being reduced to a minimum. A single cam on the half-time shaft operates both valves by means of a pair of rockers illustrated separately in Fig. 4. Double concentric helical springs return the valves to their seats. The gudgeon pin, as will be noted is clamped into the small end of the connecting rod and oscillates in the piston bosses. These and all other wearing surfaces are of unusually large size. The piston is fitted with two rings, the lower one being a scraper ring. This works in conjunction with an oil groove below it, whence oil is fed by means of the drilled hole shown, to the gudgeon pin bearings. The standard engine, as illustrated, is capable of propelling the machine at speeds up to about 50 m.p.h.

Like all modern motor cycles, the Raleigh machine is fitted with change-speed gear to enable the engine to develop its full power when the vehicle is running at less than its maximum speed. The Raleigh Company do not manufacture this gear themselves but fit the type made in the neighbouring works of the Sturmey-Archer Company. The Sturmey-Archer gear is illustrated in Figs. 5 to 11 on the opposite page. One of its special features is that the gear-wheels are continuously fully in mesh, gear-changing being effected by sliding dogs, so that there is no danger of stripping teeth when changes are made. Figs. 5 and 6 show the general arrangement of the three-speed gear. This gives speeds in the rates of 1 : 1·5, 2·9 and weighs complete only 18·5 lb. Referring to Fig. 6, when the lever shown at the right hand end of the spindle is rotated by means of a Bowden wire from the handle bar lever the friction clutch at the other end of the spindle is tightened and the sprocket wheel caused to drive the main shaft. This sprocket wheel is, of course, driven by a chain direct from the engine. Just inside the casing is a large gear wheel A, mounted in ball bearings and furnished with a sleeve extension which carries the V pulley for the final belt drive. The main axle passes freely through this gear wheel, and beyond it it is splined to receive a sliding pinion B. A third pinion C is keyed to the shaft, the end of which runs in a Skefko self-aligning bearing. The counter-shaft, shown below the main shaft in the illustration, has a pinion D keyed to its end, this pinion being constantly in mesh with wheel A. The central portion of the countershaft is plined to receive pinion E which is in constant mesh with B. These two pinions move together to obtain various speed ratios. Pinion F is called the low gear and "kick-starter" pinion and is constantly in gear with C. Apertures are cut in one side to receive the dog clutches of pinion E, and the other side is bored out and provided with internal ratchet teeth which are engaged by the part G, shown more clearly in Fig. 7. The kick starter lever is cottered to the external projection of a piece H on the centre line of the countershaft. This piece runs in a hardened steel bush driven into the casing, and carries at its other end the ratchet G. It is also bored and bushed to form a bearing for the end of the counter-shaft.

Top gear is obtained by sliding pinion B to the left so that it clutches into wheel A. The drive then is "solid" from the sprocket wheel to the belt pulley and both rotate at the same speed. To obtain middle gear, pinions B and E are moved to the left so that the splines are engaged. The drive from the sprocket wheel is then through B and E to the countershaft and through D and A to the pulley. For neutral gear, pinions B and E are moved clear of the splines on their respective shafts, as in Fig. 6. Low gear is obtained by securing wheel F to the lay shaft by moving E to the right so that the dogs engage. The drive is then through C and F to the countershaft and back through D and A to the pulley.

The kick starter mechanism is operated by depressing the crank cottered to the piece H in Figs. 6 and 7. The crank is shown in position in Fig. 5. This causes the part G to engage with the ratchet teeth in the wheel F and the engine is thus driven by means of the sprocket wheel through the gearing F and C. When the kick-starter crank is released it is returned to the vertical position by a spring, and the pawl is then held out of engagement with the ratchet teeth by the pressure upon it of the little cam piece as shown in Fig. 7.

Fig. 8 illustrates the lever arrangement for operating the gears inside the box. When the external lever is moved into position for another gear, the spring is compressed by means of a V mechanism, but the gear does not change until the clutch is released. The moment this is done the spring forces the two parts of

THE RALEIGH 2·75-H.P. MOTOR CYCLE.

CONSTRUCTED BY THE RALEIGH CYCLE COMPANY, LIMITED, LENTON, NOTTINGHAM.

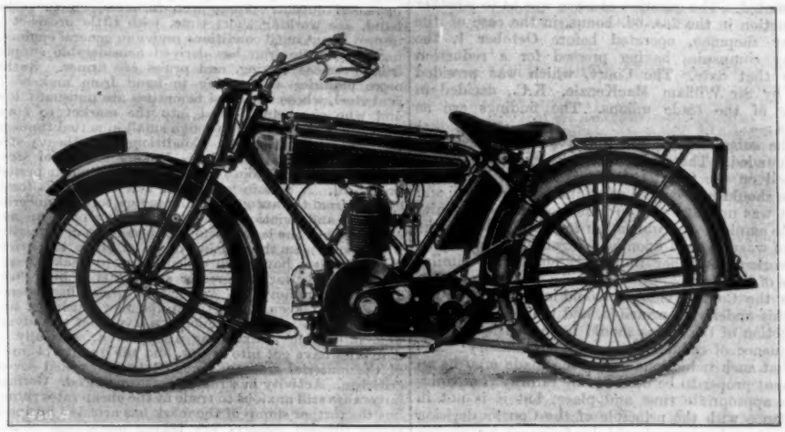


FIG. 1

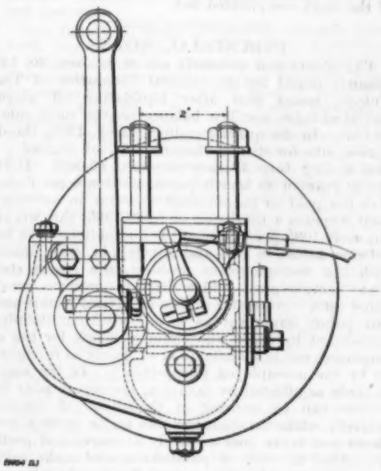


FIG. 9.

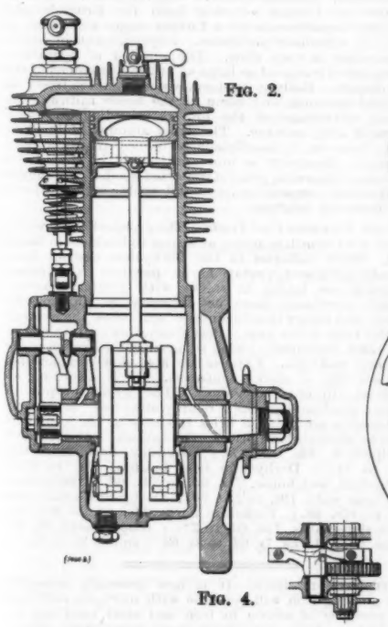


FIG. 2.

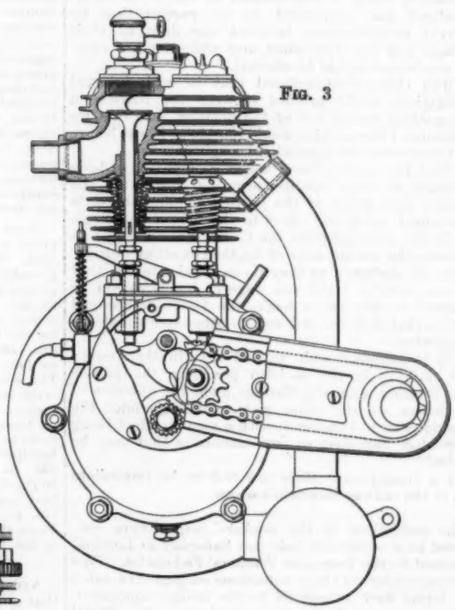


FIG. 3.

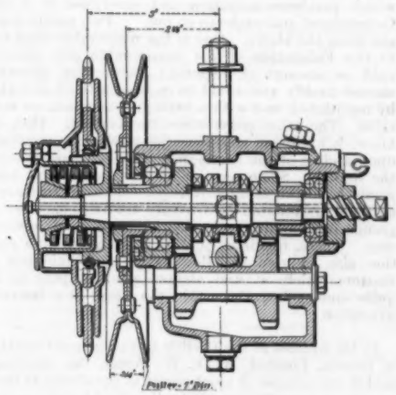


FIG. 10.

FIG. 4.

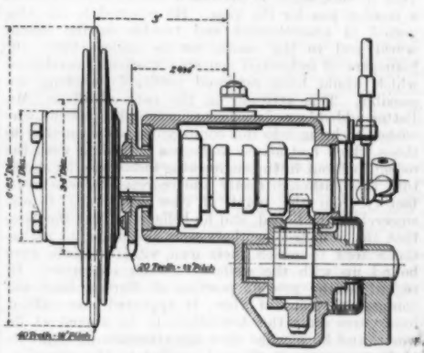


FIG. 11.

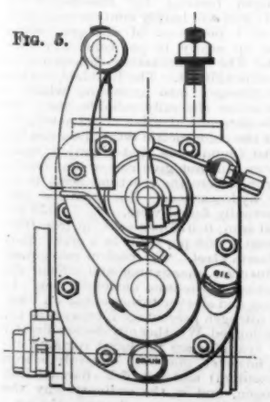


FIG. 5.

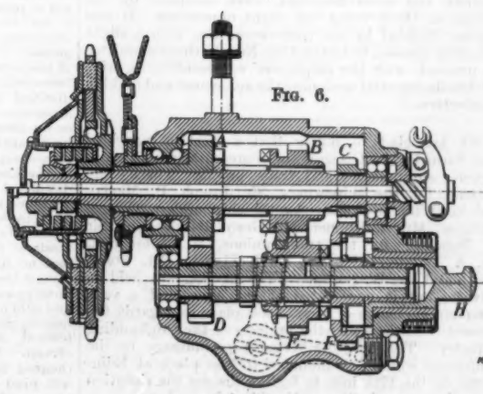


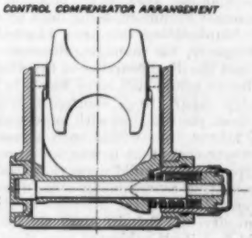
FIG. 6.

FIG. 8.

CONTROL COMPENSATOR ARRANGEMENT

FIG. 7.

KICK STARTER ARRANGEMENT



the V mechanism into line again and the required gear change is instantly effected. The two speed gear-box is illustrated in Figs. 9 to 11. It is naturally simpler than the three-speed box, but it follows along the same general lines of design, and the mechanism will be followed without difficulty in view of our description of the more complicated box.

INDUSTRIAL NOTES.

THE ninety-first quarterly report, to June 30, 1922, recently issued by the General Federation of Trade Unions, states that after liquidating all accrued liabilities there is still a balance on the right side of 56,705*l.* In the quarter ending March, 1922, the disbursements for dispute benefit totalled 18,380*l.*; in that ending June 30 they exceeded 87,000*l.* During the 22 years of its benefit-paying existence the Federation has paid to its affiliated societies on account of their disputes a total sum of 1,080,396*l.*, this working out at 49,108*l.* per year, but the fluctuations have been between 4,068*l.* in 1901 and 219,696*l.* in 1920. Dealing with the unemployment problem, the report states that "employment which fails to produce greater value than it consumes invites industrial bankruptcy; this point, important as it is, is seldom definitely enunciated by those who claim to speak for the unemployed, nor is it understood as clearly as it ought to be by the unemployed themselves." In the matter of trade as affected by taxation, the report adds that "there can be nothing in the shape of complete recovery while taxation remains at its present level. Rates and taxes, just as surely as wages and profits, are added to costs of production, and make selling prices higher and selling more difficult. Any Government which is unable to relieve its people of taxation, which paralyses initiative and enterprise, is a bad Government and ought to go out." Two points stand out from the above. One is the regrettable dead loss to the Federation of the considerable sum quoted, paid on account of disputes; these were probably started hastily and could have been settled amicably by negotiation and with a little give and take on both sides. The other point refers to taxation. This, we know, is excessive and bears heavily more especially upon a class of the community who can hardly carry the burden. Some amount of relief under this head would be forthcoming were it possible to entrust every national transaction of a purely trading character to groups or committees formed exclusively of business men. These, by virtue of their training, are in a position also to give valuable advice and guidance in matters which, at first glance, would appear to be quite and exclusively within the scope of a lawyer's avocation.

In his address at the twelfth annual general meeting of Potters, Limited, Mr. E. W. Potter, the chairman, said it was a cause of great regret to the directors that, in spite of unremitting efforts, they had for the second year in succession to present accounts which showed a trading loss for the year. He referred to the long period of unsettlement and trouble in the labour world and to the endeavour to impose upon the managers of industrial concerns workshop conditions which would have rendered profitable working impossible. This attitude on the part of labour, Mr. Potter added, was largely engineered by persons who wished to bring into this country conditions similar to those which had arisen in Russia. Dealing with the recent lock-out in the engineering industries, he stated that this, although costly and regrettable, was satisfactory from the point of view aimed at; it was sincerely to be hoped, and he believed it was the case, that the industrial workers were beginning to realise the extent to which their own vital interests were bound up with the welfare of their industries. In regard to the present position of Europe from the commercial point of view, it appeared now—about four years after the Armistice—to be almost at its worst, and he pleaded that the attention of Members of Parliament and others be called to the situation, urging them to increase their efforts to find some means of opening up the markets which were essential to the nation's well-being.

Speaking last week on the occasion of the launch of the steamer Fernmore, being built by the Northumberland Shipbuilding Company Limited, Sir Alexander M. Kennedy, the managing director of the company, said that the disappearance of the whole of the 26*s.* 6*d.* war bonus would still leave wages in the shipbuilding industry—apart from shortened hours—at a higher cost than pre-war, but with improved output it would bring labour costs within such a measurable distance of pre-war costs that it was not unreasonable to look to shipowners to build upon that basis and search for compensating economies in other directions. It could not possibly be in the interests of the great shipping community of Britain that the shipping industry should find itself subjected to a time of depression so prolonged as to take the heart out of both workmen and employers.

The question of railway shopmen's wages came before the Industrial Court a few days ago, both the railway companies and the trade unions concerned being represented. The question at issue was as to whether a reduction in the 26*s.* 6*d.* bonus, in the case of the railway shopmen, operated before October 1, the railway companies having pressed for a reduction before that date. The Court, which was presided over by Sir William MacKenzie, K.C., decided in favour of the trade unions. The findings are as follows:—

"The submission of the railway companies is not well founded. The decision clearly indicates that it is based on the Court's conclusion that the railway service should be regarded as an industry in itself, and that it was not desirable to impose on the companies and the employees an obligation to adopt or follow the rates of wages agreed upon or recognised by employers and workers in other industries employing similar classes of labour.

"In the Court's view it would not be consistent with this underlying principle, and their decision that a reduction of the bonus should be made simply as a consequence of reductions in another industry. The fact that such reductions have been made may be an argument proper to be used by the railway companies at the appropriate time and place, but it is not in accordance with the principle of the Court's decision that such reductions should be followed by similar reductions in the case of railway shopmen, as an immediate and necessary consequence.

"As the provisions affect the workmen at a very large number of places, and involve many alterations in existing rates, it was deemed by the Court to be expedient and convenient to the parties that an interval should elapse between the date of their findings and the date when any alterations of rates and conditions should be effected.

"The Court contemplated that in such interval negotiations would proceed between the parties on any matters arising out of the decision, but that up to October 1 the position would remain as it was before the Court when their decision was given.

"Had the interval been longer it might have been necessary to make specific provision respecting the position and duties of the parties pending the date determined for giving effect to the detailed findings, but in the circumstances the Court saw no object in requiring the maintenance of the then existing position. Hence, in declaring as they do in precise terms, that as from October 1 the war wage or bonus should be regarded as 26*s.* 6*d.* a week, the Court determined that on that date 26*s.* 6*d.* and no other sum should be in operation.

"It is necessary only to add that in the Court's view nothing in the decision precludes the parties from entering upon negotiations upon the question of war bonus, or any other matter arising under the decision prior to October 1, with a view to effect being given after that date to any conclusion that may be reached."

As a consequence there are not to be immediate cuts in the railway shopmen's wages.

The reductions in the dockers' wages were considered at a conference held last Saturday in London, convened by the Transport Workers' Federation. (We gave particulars of these reductions on page 214 *ante*.) The terms were submitted to the unions concerned, with a recommendation for acceptance. An official report issued after the conference stated that a memorandum, signed by the Negotiating Committee, together with a schedule and analysis of the decisions of district and mass meetings, were accepted by the delegates, there being but slight opposition. It was further decided by the conference, also with a slight minority against, to instruct the Negotiating Committee to proceed, with the employers' representatives, with all details essential to signing the agreement and making it effective.

We are glad to notice that a meeting was held last Saturday in Glasgow, of representatives of shipowners, shipbuilders and trade unions. There were present, for the shipowners, Sir Joseph P. Maclay and Sir William Noble; for the shipbuilders, Colonel Lithgow, Mr. L. Ropner, Mr. Grant Barclay and Sir A. Duncan; for the trade unions, Mr. John Hill, Mr. A. Wilkie, M.P., Mr. A. H. Findlay, Mr. Frank Smith and Mr. W. Lorimer. The meeting was held in private, but it was stated at the close that a very complete exchange of views took place as regards the present conditions and the projects of the shipbuilding industry. This meeting forms a preliminary to the conference which is announced to take place at Edinburgh on the 12th inst. to further discuss the situation and a further reduction in the 26*s.* 6*d.* war bonus.

NOTES FROM SOUTH YORKSHIRE.

SHEFFIELD, Wednesday.

Iron and Steel.—In the market for raw and semi-finished materials interest is centred principally in basic iron and soft steel. Furnaces producing the former have better order books than for several months past, and have no difficulty in disposing of the whole of their increased output. Forge iron furnaces, on the other hand, are working short time, with little prospect of improvement until conditions revive in general engineering. Hematite iron has derived considerable support from overseas buying, and prices are firmer. Rather more inquiries are coming to hand from makers of acid steel, whose stocks of hematites are unusually low, and who are being forced into the market to cover the latest orders, which, though small in actual tonnage, are increasing in number. Conditions in the heavy steel trades show wide variation. Makers of special steels are just emerging from one of the most difficult periods on record. A certain volume of new business is forthcoming from the automobile and agricultural engineering sections, and aviation developments may open up new channels, but the last has not yet been seen of expensive war stocks. In the writing down of these to current values holders have been called upon to make heavy sacrifices. By far the greater activity is in bulk steel. The recent removal of Association prices has opened the door to keen competition for new business, and values have reached so economic a level that the advantage of buying abroad has disappeared, especially as deliveries have got into arrear, and the quality of much of the material recently received has provoked severe criticism. Activity in scrap is less pronounced. German buyers are still anxious to trade at the cheap rates ruling, but the further slump of the mark has arrested business. Home furnace masters are taking advantage of the position to augment depleted stocks against more active conditions. The market for alloys is uniformly dull. Higher prices are only being quoted in exceptional cases to cover increased costs. Crucible steel is still a difficult market, though deliveries to America are rather more substantial. Agreements have been reached with a large number of Unions covering both the Crucible and Siemens Departments for a further wages reduction, in order to stimulate purchases. Improvement in heavy engineering is very slow. The number of operatives unemployed is almost as large as at the settlement of the last dispute. Railway business is moving more freely on Colonial account, and some of the home railways are taking advantage of the low rates ruling to place renewals long overdue. The gross amount of business done, however, is insufficient to occupy plants at half pressure. Recovery is more noticeable in the lighter sections. The rising price of imported goods has spragged continental competition in small tools, and prospects are distinctly brighter.

South Yorkshire Coal Trade.—The prospect of increased prices next month is acting as a spur to business in house coal. Some collieries in the Derbyshire district have already advanced quotations 1*s.* per ton. Consumers generally are laying in stocks with greater freedom, though merchants have no difficulty in coping with orders, and report that business is well below the average for this time of the year. Best steams are maintained at firm rates, principally owing to increased deliveries made to home railways. Exports are also slowly expanding. The scarcity of slacks continues, and is affording an artificial stimulus to values. The whole output of furnace and foundry coke is readily absorbed. Exporters to America are doing a brisk business in the former at rates 5*s.* above inland prices. Quotations:—Best branch handpicked, 36*s.* to 37*s.*; Barnsley best Silkstone, 33*s.* to 34*s.*; Derbyshire best brights, 23*s.* to 24*s*; Derbyshire best house, 21*s.* 6*d.* to 22*s.* 6*d.*; Derbyshire best large nuts, 19*s.* to 21*s.* 6*d.*; Derbyshire small nuts 15*s.* to 16*s.* 6*d.*; Yorkshire hards 21*s.* 6*d.* to 22*s.* 6*d.* Derbyshire hards, 19*s.* 6*d.* to 21*s.*; rough slacks, 8*s.* 6*d.* to 10*s.* 6*d.*; slacks, 7*s.* 6*d.* to 8*s.* 6*d.*; smalls 3*s.* to 5*s.*

NITROGEN IN IRON.—It is now generally accepted that glowing iron will combine with nitrogen, and that the presence of nitron in iron and steel need not be ascribed to their containing some manganese, silicon or other constituents which take up the nitrogen more readily than iron does. According to F. Wüst and J. Duhr (Mitteilungen Institut für Eisenforschung, vol ii, pages 39 to 57) iron will hardly contain more than a few hundredths of 1 per cent. of nitrogen, whilst chromium may take up nearly 10 per cent. and manganese 7 per cent. The quantitative determination of the nitrogen in iron is difficult. The Kjeldahl method (conversion of the nitrogen into ammonia, which is distilled off) seems to be the only reliable one; the ammonia can then be determined either colorimetrically, or by titration; but the colorimetric estimation can not be trusted, and Wüst found even that titration, using iodo-eosin as indicator, did not give concordant results in the case of pig-iron, where the reactions seem to be disturbed by some hydrocarbons. The nitrogen percentages which he actually found were, *e.g.*, 0·0029 per cent. in Swedish nail iron, 0·016 per cent. in iron from electric furnaces, about 0·006 per cent. in a great many kinds of Siemens-Martin steel. The carbon percentage had no distinct influence; manganese and silicon did favour the nitrogenation of the iron, nickel did not. In most cases, in pudding and electric furnaces and on basic and acid hearths the nitrogen percentage increased as the heating period was prolonged. Whether nitrides are directly formed, or whether cyanides are produced remains uncertain. It is clear, however, that both electrolytic iron (heated first in a vacuum) and Swedish charcoal iron will bind pure nitrogen, and in the ordinary way the nitrogen is most likely taken up directly from the air.

NOTES FROM CLEVELAND AND THE NORTHERN COUNTIES.

MIDDLESBROUGH, Wednesday.

The Cleveland Iron Trade.—Business in Cleveland pig iron continues slow, but the outlook is rather more encouraging. With foundries a little better employed, and more inquiry reported in other consuming industries, home demand promises to improve. Trade with the Continent is still within narrow limits, and the future depends largely on the course of notes of exchange, but a steady business is passing with America, purchases for the States consisting of pig-iron low in phosphorus, and sulphur, ferro-manganese iron, and other special products of this district. Great scarcity of No. 1, and siliceous iron keeps those descriptions at the comparatively high figure of 95*s.*, but other qualities are in ample supply, and No. 3 G.M.B. is obtainable at 87*s.*; whilst No. 4 foundry runs from 85*s.* to 86*s.*; No. 4 forge ranges from 82*s.* 6*d.* to 84*s.*; and mottled and white are in the neighbourhood of 80*s.*—all f.o.t. makers works, or f.o.b. Tees. At the same time, whilst home and export orders can be placed at these figures, some producers are asking a rather higher price for No. 3 for shipment abroad.

Hematite.—Recent moderate sales of East coast hematite include parcels of special iron to the United States. Makers are inclined to take a rather firmer stand, but as output is still in excess of requirements, they are anxious to secure contracts. Home customers report that they experience no difficulty in placing orders for Nos. 1, 2, and 3 at 90*s.*, and for overseas trade the price is in the neighbourhood of 89*s.* No. 1 hematite is no more than 6*d.* above mixed Nos.

Foreign Ore.—As yet no movement is noticeable in the direction of improvement in demand for foreign ore, and beyond occasional sales of odd cargoes, business is at a standstill. There are sellers of best rubio at 24*s.* 6*d.* c.i.f. Tees and good Mediterranean ores are round about 23*s.* c.i.f. Tees.

Blastfurnace Coke.—Durham blastfurnace coke quotations are irregular. For average qualities, sellers ask 26*s.* 6*d.* to 26*s.* 9*d.* delivered, but local consumers show marked disinclination to pay such rates, and report that they can satisfy their needs on lower terms.

Manufactured Iron and Steel.—A little better account may be given of some branches of finished iron and steel. The lower prices have brought in a few orders, but many firms have little work on hand. Some of the large steel works have not yet re-started after last week's annual local holiday. Common iron bars are 11*l.*; black sheets, 12*l.*; galvanized corrugated sheets, 16*l.* 10*s.*; steel ship, bridge, and tank plates, 9*l.*; steel boiler plates, 12*l.* 10*s.*; steel angles, 8*l.* 10*s.*; steel joists, 9*l.*; and heavy sections of steel rails, 9*l.* 10*s.* Export orders can be placed at substantially below the foregoing figures, which are the quotations for home trade.

NOTES FROM THE NORTH.

GLASGOW, Wednesday.

Scottish Steel Trade.—While there has been very little development in the Scottish steel trade during the past few weeks, despite the easier prices now prevailing, there is undoubtedly a more optimistic spirit. One or two branches of industry have lately booked some fairly satisfactory lines—satisfactory in these times only perhaps—but which would seem to show that all is not over with trade in this country yet. The local steel-makers have received a small share also and there are prospects of other lots to follow. The intimation that several new steamers have been fixed up by Clyde ship-builders has given a little impetus to the trade and keen competition has been the order of the day to secure the business. Plate mills have been doing very poorly for a while back and any improvement will be gladly welcomed. Inquiries are fairly plentiful but up till now there has been little result in the way of business. Sectional material is in moderately good demand but other departments are still going very slowly. Black sheet makers report that home consumers are not purchasing much at present but thin gauges for export are the subject of very good business. Prices all round have an easier tendency, but the following are named as to-day's quotations:—Boiler plates, 12*l.* 10*s.* per ton; ship plates, 9*l.* per ton, although less is understood to have been accepted; sections, 8*l.* 15*s.* per ton; and sheets, ¼ in., 10*l.* 5*s.* per ton, all delivered Glasgow stations.

Malleable Iron Trade.—The state of the malleable-iron trade of the West of Scotland shows little change and the outlook is not just too clear at the moment. Home dealing is not of much account and most of the business passing is for export. Prices are unaltered with "crown" bars called 10*l.* 10*s.* per ton delivered Glasgow.

Scottish Pig-Iron Trade.—Quite a good tone prevails in the Scottish pig-iron trade with prices continuing firm. Foundry grades are still in good request for shipment, but the home consumption shows little change. In hematite iron the prospects are better owing to the improved outlook for steel, but so far the demand is not very heavy. The current quotations are as follow:—Hematite iron, 5*l.* 7*s.* 6*d.* per ton, delivered at the steel works; and foundry iron No. 1, 5*l.* per ton, with No. 3, 4*l.* 15*s.* per ton, in trucks at makers' works.

Clyde Shipbuilding.—The shipbuilding industry on the Clyde shows little improvement yet and there is a great deal of unemployment, but quite a number of inquiries are in the market. Many of these are only looked upon as "feelers" and it is very doubtful if contracts will result. The cost of construction is considered to be too high yet to induce owners to place orders for general cargo carrying vessels. While new business has been very scarce for a long time it is gratifying to record the fact that contracts were recently placed on the Clyde for several special steamers. Messrs. John Brown and Co., Clydebank, have booked orders for two cable steamers for one of the leading cable companies. Messrs. Barclay, Curle and Co., Whiteinch, are to build and engine another liner for the British India Steam Navigation Company, and Messrs. Chas. Connell and Co., Scotstoun, are building two steamers for Anglo-Asiatic owners.

NOTES FROM THE SOUTH-WEST.

CARDIFF, Wednesday.

The Coal Trade.—Though there is still a good inquiry for Welsh coal on American and Canadian account, few orders have been placed recently. The demand from the Continent and Europe is very quiet, and but for the fact that large orders had already been placed by America and Canada, about half the South Wales pits would have been idle or working short time. As it is, shipments at the docks are actively proceeding. Prices generally however, are weaker. Best dry large is, however firm, at 30*s.* to 31*s.*, but best Admiralty large can be secured at 30*s.* and the leading Monmouthshires round 28*s.* while best steam smalls are steady at 21*s.* Sized coals are scarce, with dry nuts firm at 35*s.* and bituminous nuts at 27*s.* 6*d.* Anthracites are practically unobtainable and for cobbles 75*s.* is firmly demanded with large at 63*s.* Of the 498,372 tons of coal shipped abroad last week, 138,721 tons, or 28 per cent. of the total, went to the United States and Canada. Four cargoes totalling 26,230 tons were destined for Boston (Mass.), 14 of 83,988 tons for New York, 2 of 11,898 tons for Providence (Rhode Island), 1 of 7,456 tons for Philadelphia, 2 of 3,229 tons for St. John N.B., and 1 of 5,920 tons for other parts of the States. A further 18 steamers to carry 106,200 tons were chartered on the open freight markets during the week, of which 14 of 83,200 tons were for New York options, 1 of 7,000 tons for Providence and 3 of 16,000 tons for Montreal, which brings the total since July 17 last to 168 steamers to carry 1,262,600 tons of Welsh coal to the States and Canada. Shipments to France last week amounted to 130,753 tons, to Italy 63,975 tons, to South America 33,170 tons, to Spain 46,118 tons, to Portugal 12,358 tons, to British coaling depots 31,342 tons and to other countries 41,935 tons.

Fascisti Ship Held Up.—The Italian steamer Emanuele Accame with a Fascisti crew arrived at Cardiff yesterday, and is "boycotted" by the coal trimmers and tippers, who have been instructed by the National Transport Workers' Federation and the National Union of Railwaymen respectively, not to handle the vessel on the grounds that the Fascisti crew are members of an organisation which, in Italy, have burnt down Trade Union offices and are opposed to trade unions. The position is being inquired into locally by representatives of the trimmers and tippers and it is believed that the vessel, which is going to New York, will be loaded in the ordinary way. The Fascisti, it may be stated, are simply an anti-Bolshevik organisation, and its members include many trade unionists.

Iron and Steel.—The export trade is quiet. Continental buying is very restricted owing to the adverse exchange rates, but a few parcels are going to South America, and bookings on Canadian account are expected. The home demand is fairly satisfactory, and prices keep steady on the basis of 19*s.* 1½*d.* to 19*s.* 3*d.* for standard boxes. There was a heavy reduction in shipments last week. In all, 6,424½ tons of iron and steel goods were exported compared with 10,034½ tons in the previous week. Last week's exports consisted of 691 tons of blackplates, 3,676 tons of tinplates, 1,460 tons of galvanised sheets, and 597½ tons of iron and steel.

HYDRO ELECTRIC DEVELOPMENTS IN CANADA.—A project for a new canal 80 ft. wide, crossing the Chippawa river, has recently been announced by Sir Adam Beck, Chairman of the Hydro Electric Power Commission of Ontario. The completion of the proposed canal, which would be twice the capacity of the Chippawa canal, would enable a total of no less than 1,750,000 h.p. to be developed on the Canadian side of Niagara Falls. Such a canal would cost $100,000,000, but the Hydro Commission anticipate no difficulty with regard to finance, in view of the high credit of the undertaking, which has a present investment of $230,000,000. The energy and enlightened policy of the Commission have been of incalculable benefit to Ontario, and *mutatis mutandis* its activities might serve as an admirable example to our own Electricity Commissioners.

REMOVAL OF PHOTOGRAPHIC FILMS FROM GLASS PLATES.—The removal of the silver film from photographic negatives for the purpose of recovering both the silver and the glass plate is hardly considered worth while over here, but has received attention in Germany owing to the general dearth of materials. Professor Fritz Limmer, of Darmstadt (*Chemiker Zeitung*, July 20), having tried with little success to remove the film by means of nitric acid, soda, hot water and superheated steam, found the double ammonium fluoride known as matt salt suitable for the purpose. This salt is less corrosive to glass and less dangerous and troublesome generally than hydrofluoric acid. The salt is dissolved in cold water, so as to yield a solution of not more than 2 per cent., in which the plate is placed for a few seconds. The film then peels off readily and can be kept intact if dried on cardboard, to which it will not stick if removed again before complete drying. The water should not be hard; distilled water or rain water should be used. The varnish of varnished plates should first be washed off with the aid of spirit and cotton wool.

NOTICE OF MEETINGS.

THE INSTITUTION OF RUBBER INDUSTRY.—Monday, September 4, at 7.30 p.m., in the Watt Room, Engineers' Club, Coventry-street, W. A paper by Mr. F. Kaye, entitled "Rubber Latex in Paper Making," will be read and discussed.

THE IRON AND STEEL INSTITUTE.—General Meeting, York, September 5 to 8, in the Tempest Anderson Hall of the Museum of the Yorkshire Philosophical Society. The following papers will be read and discussed, Tuesday, September 5, at 10 a.m.: "The Bases of Modern Blast Furnace Practice," by A. K. Reese, Tuesday, September 5, at 2.15 p.m.; "The Diminution of Lag at Ar1 through Deformation," by J. H. Whiteley; "Nitrogenisation of Iron and Steel by Sodium Nitrate," by L. E. Benson; "An Investigation on the Factors Influencing the Grain and Bond in Moulding Sands," by C. W. H. Holmes, Wednesday, September 6, at 10 a.m.; "Some Experiments on the Flow of Steels, at a Low Red Heat, with a Note on the Sealing of Heated Steels," by J. H. S. Dickenson; "The Changes of Volume of Steels during Heat Treatment (1. Air Hardening Nickel Chromium Steels)," by L. Aitchison and G. R. Woodvine; "Practical Notes on the Manufacture and Treatment of High Speed Steel," by H. K. Ogilvie; "A Brinell Machine attachment for use with Small Specimens," by E. D. Campbell; "A Preliminary Magnetic Study of some Heat-treated Carbon Steels," by E. D. Campbell and E. R. Johnson. Visits to works and other places of interest have been arranged.

THE BRITISH ASSOCIATION; SECTION G.—Wednesday, September 6 to Wednesday September 13, in the City Hall, Hull, under the presidency of Professor T. Hudson Beare, M.Inst.C.E. Particulars of the programme arranged were given on page 177 of our issue of August 11, certain alterations in the original arrangements being noted on p. 243 of our issue of August 25.

INSTITUTION OF MUNICIPAL AND COUNTY ENGINEERS.—The Eastern District Meeting is to be held at Luton, on Saturday, September 16. Arrangements have been made whereby members may visit the Luton Borough Gas, Electricity and Waterworks; the Luton Rural District Council Housing Scheme at Houghton Regis; an old British Camp, Maiden Bower, British Road and Roman Camp; the Sewage Disposal Works of the Dunstable Corporation.

THE INSTITUTE OF METALS.—A notable feature of the forthcoming Swansea meeting of the Institute will be the inauguration of a series of annual public lectures on "Subjects of Practical Interest to those engaged in the Non-Ferrous Metals Industry." The lectures are additional to the well-known annual May lectures of the Institute, which have constituted a special feature of the Institute's work since 1910. Dr. R. S. Hutton, a Member of Council of the Institute, and Director of the British Non-Ferrous Metals Research Association, is to deliver the first of the new lectures, this being entitled "The Science of Human Effort (Motion Study and Vocational Training)." The lecture will be given at 8 p.m. on Tuesday, September 19, at the Y.M.C.A., Swansea. Tickets can be obtained from Mr. G. Shaw Scott, Secretary, 36, Victoria Street, London, S.W. 1.

"THE COMPOUNDING OF A TRIPLE-EXPANSION ENGINE."—With reference to our article which appeared on August 18 last describing the alteration of a large Corliss mill engine from triple expansion to compound working for the sake of increasing its power, we are requested to state that the change was completely effected during the stoppage of the mill for the annual seven days' holiday, so that no productive time was lost. As the work involved fitting a new high-pressure cylinder, and standard, replacing the piston rods, cross-heads and connecting rods of the high and low pressure cylinders by larger ones; and also providing an additional air pump and condenser, the rapidity with which it was carried out is very creditable to Messrs. Geo. Saxon, Limited. All new parts were of course made in readiness for the change, but its completion within a week is evidence of the foresight and energy displayed by the firm.

MINING REGULATIONS IN THE UNITED STATES.—Operating regulations to govern the methods of mining oil shale, phosphate, sodium, and potash on leased public lands of the United States have just been issued by the Bureau of Mines, which is entrusted with the supervision of such operations. The regulations provide that it shall be the duty of the supervisor and district mining supervisors to visit from time to time leased lands where operations for the discovery or mining of oil shale, sodium, phosphate, or potash are conducted; to inspect and supervise such operations with a view to preventing waste of mineral products, or damage to other mineral deposits; and to supervise operations and conditions for the promotion of the safety, health, and welfare of workmen. The lessee shall prepare such maps as in the judgment of the mining supervisor are necessary to show the surface boundaries, improvements, and topography, and the geological conditions so far as determined from outcrops, drill holes, prospecting, or mining. The underground and surface sanitary, welfare, and safety arrangements shall be in accordance with the recommendations of the United States Public Health Service and United States Bureau of Mines and are adequately provided for.

150-TON SELF-PROPELLED FLOATING CRANE.

CONSTRUCTED BY WERF GUSTO, FIRMA A. F. SMULDERS, SCHIEDAM, HOLLAND.

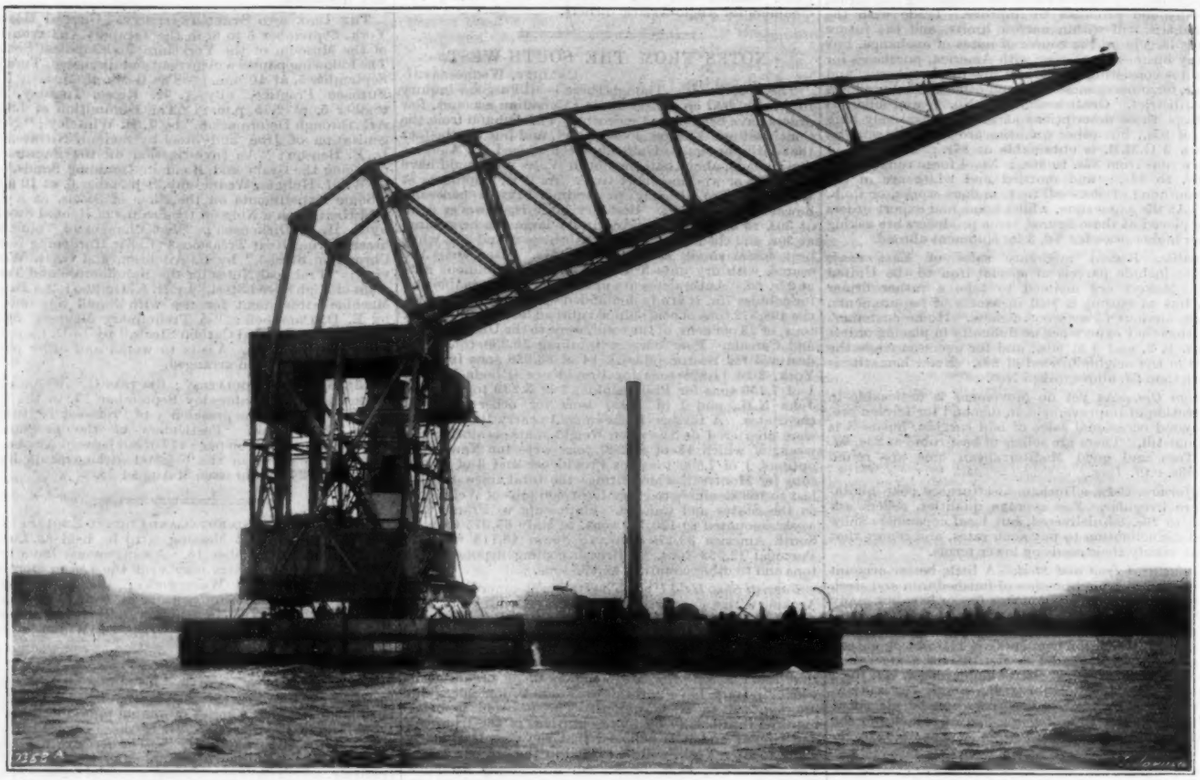


FIG. 1.

A 150-TON self-propelling floating crane was recently delivered to Messrs. Swan, Hunter and Wigham Richardson, Limited, of Wallsend-on-Tyne, by the Werf Gusto, Firma A. F. Smulders, Schiedam, Holland, whose London office is 38, Victoria-street, S.W. 1. The accompanying illustrations give a very good idea of this appliance, which is named the "Titan II." Fig. 1 shows the crane proceeding under its own power, while Figs. 2 and 3 respectively show an elevation and deck plan, from which the size and range of the crane may be gathered.

The crane is of the firm's slewing and derricking type. It is provided with two blocks, one capable of handling loads up to 150 tons and the other loads of 40 tons. The 40-ton tackle has a swing of a maximum radius of 150 ft., when the greatest height of the tackle above water-level is 105 ft. The maximum height to which this tackle can be raised is 180 ft., when the radius of the load is 91 ft. The main tackle is arranged to lift loads of 150 tons at a maximum distance of 87 ft. 6 in. from the centre of the tower. For loads above 125 tons the crane is not slewed, the jib being fixed pointing out over the bows, and held in position by tie bars fastened to the base of the revolving structure and the pontoon. For the 150-ton lift the tackle can be raised to a height of 87 ft. above water level. Loads up to 125 tons can be slewed at a maximum radius of 73 ft. 9 in., and can be raised till the block is 108 ft. above water-level, or, at 55 ft. radius, another 15 ft. The 150 ft. radius for the 40-ton load corresponds to an overhang of 115 ft. clear of the pontoon. The pontoon is 131 ft. long by 69 ft. beam, and both sets of tackle can deposit their load on deck. The latter is clear of all obstructions aft, and is specially strengthened to receive heavy loads. The loads are counterbalanced by two travelling ballast weights, and by this means the pontoon can be maintained practically level for all lifts up to 125 tons. Hoisting speeds of 3 ft. and 10 ft. per minute are provided for the heavy and light tackle respectively. Slewing through 360 deg. can be accomplished with a 125-ton load, in 6 minutes.

Fig. 2.

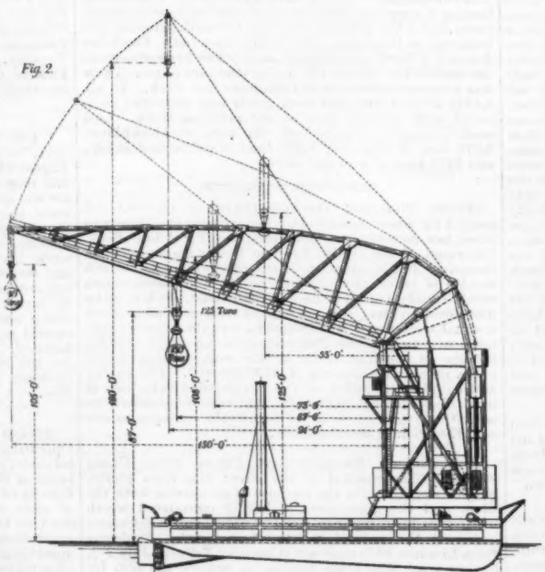
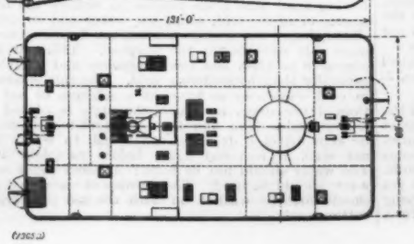


Fig. 3.



The movements of the crane are effected by electric power, the seven motors being all arranged in a winch room on the lower platform of the revolving structure, as shown in Fig. 2. The movements are all controlled by an operator in a cabin placed as shown in Figs. 1 and 2, on the upper part of the framework below the jib hinges, from which point the driver has a clear view of the load as well as of the pontoon deck. Arranged in a stand in front of the driver are controllers for all motions, while in this cabin also are placed all the required switches, measuring instruments, resistances for the electrical equipment, trim indicators, and also an indicator for the position of the jib, by which it can be seen how far the lifting hook is from the centre of the tower. Telephone communication is provided from this cabin to the boiler room and winch room below. A special emergency switch is also provided in case it is necessary to stop operations suddenly.

One man suffices to control the operation of the crane. The necessary motor control is arranged on the Ward-Leonard system, which makes possible the use of extremely slow speeds for the heavy loads. Electric brakes are fitted to all motor shafts. Limiting stops are arranged for the various movements. Numerous other safety devices have been provided. Current is supplied by a steam vertical compound set, while the propelling machinery consists of two sets of vertical compound engines with an independent condensing plant. Between the engine rooms is the boiler room. The working pressure is 147 lb. per square inch. All the necessary deck machinery is provided, and electric light is fitted for the pontoon and crane. The crane was towed from Schiedam to Wallsend without the jib being dismantled, shear legs being fitted from the jib nose to the pontoon, for the voyage.

THE CANADIAN PACIFIC LINER "EMPRESS OF CANADA."

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(*For Description, see Page* 255.)

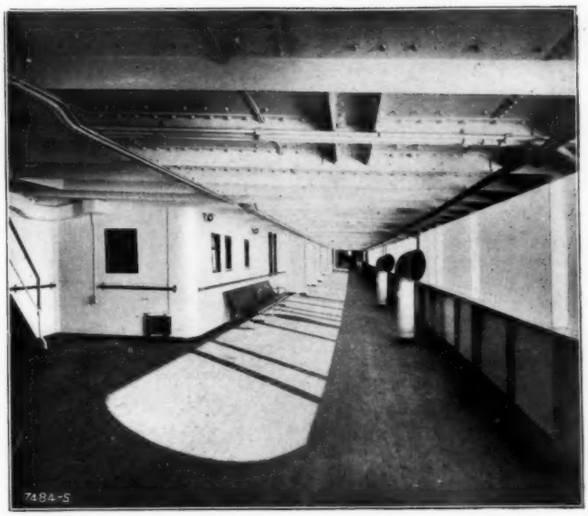

FIG. 14. AFTER PART OF PROMENADE.

FIG. 15. FORWARD PART OF PROMENADE.

FIG. 16. AFTER PART OF FIRST-CLASS LOUNGE.

FIG. 17. CARD-ROOM.

(*To face page* 256.)

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Fig.4.

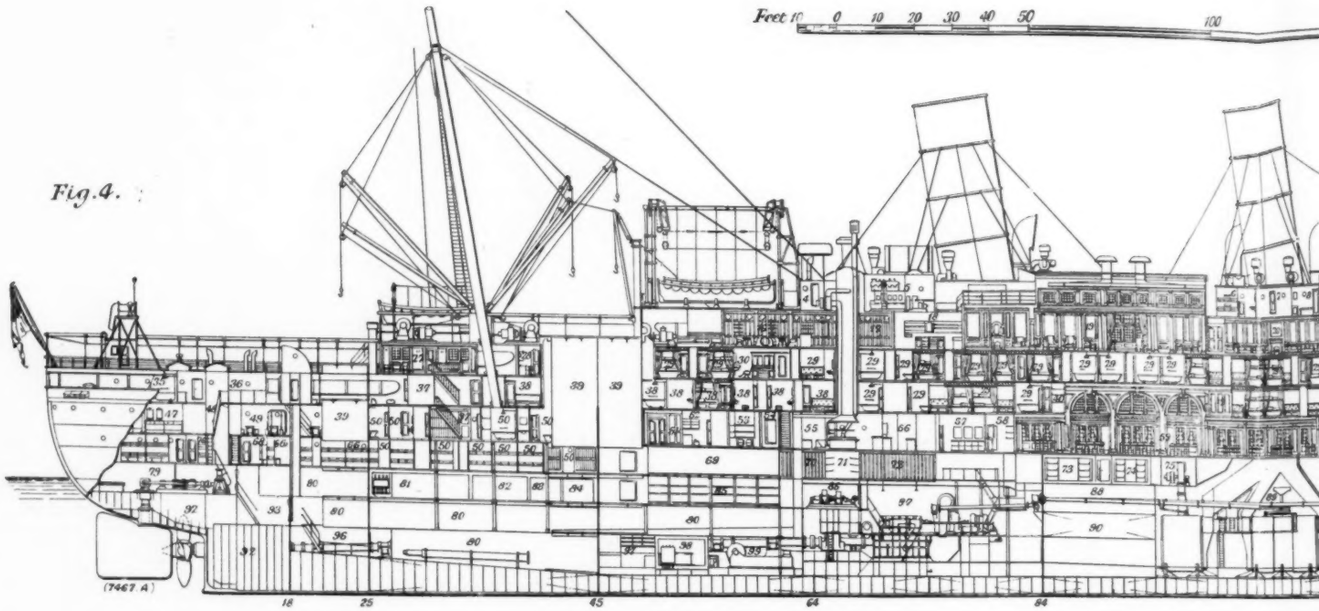


Fig.5. PROMENADE DECK "A"

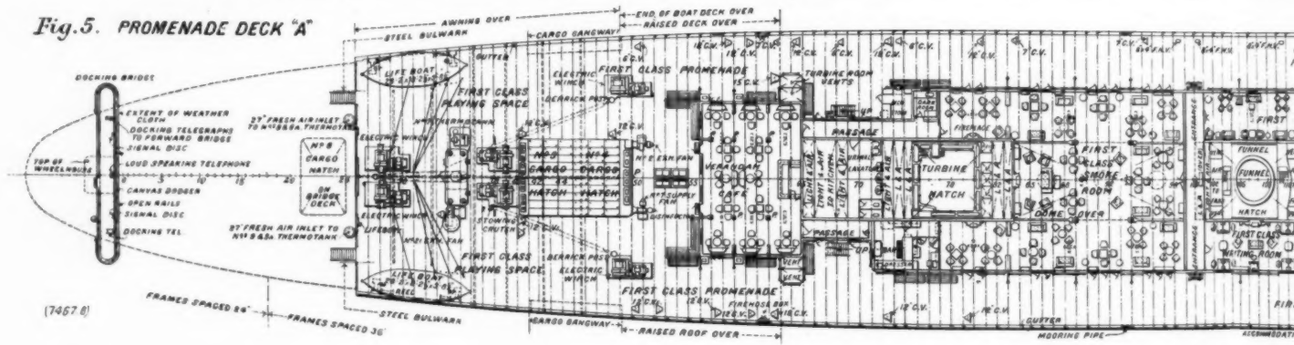


Fig.6. BRIDGE DECK "B"

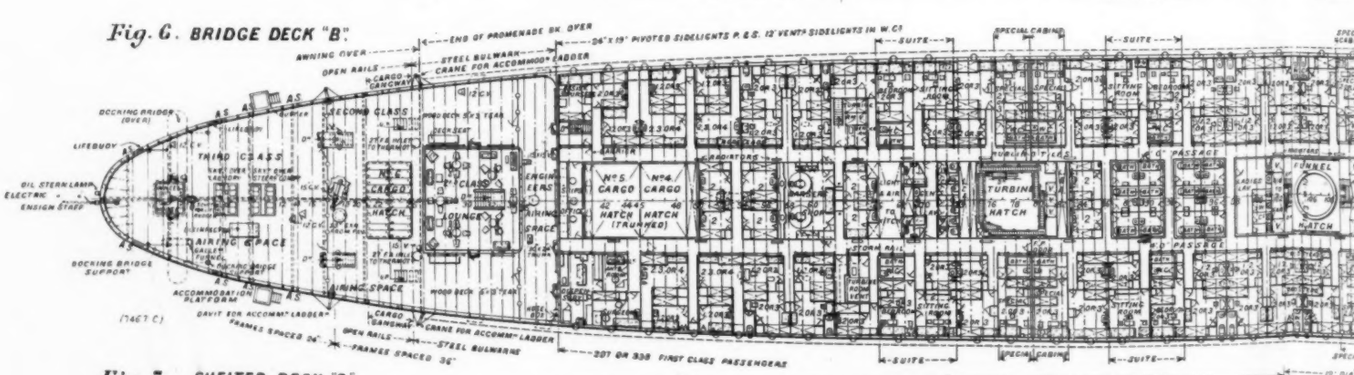
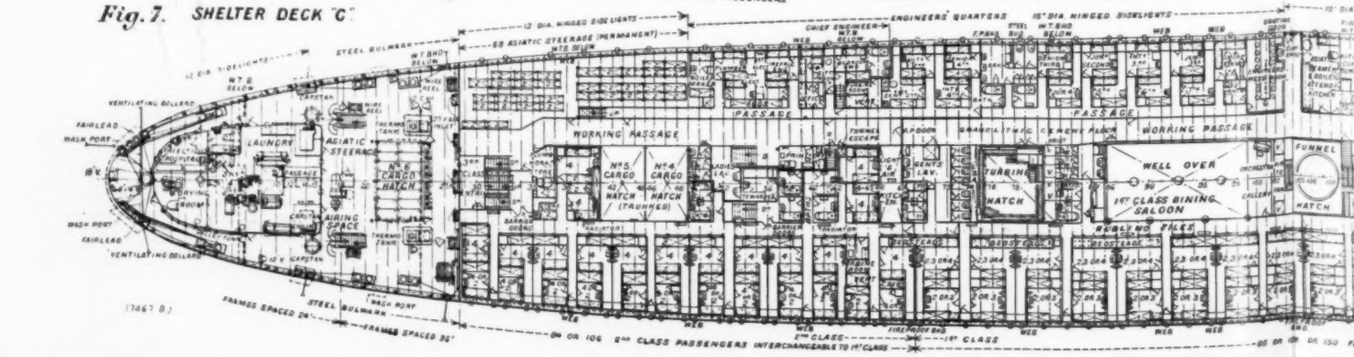


Fig.7. SHELTER DECK "C"



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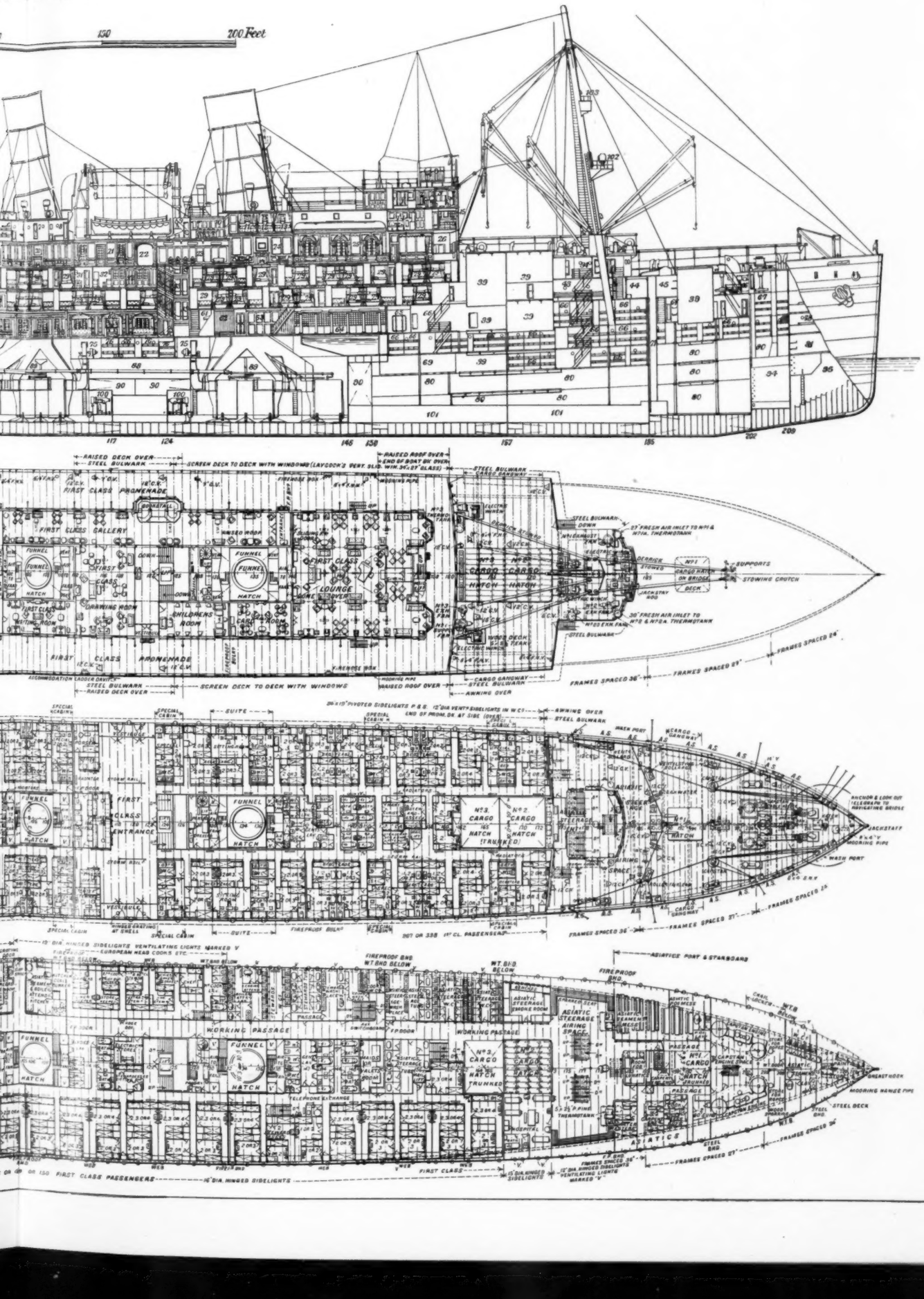

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(*For Description, see Page* 255.)

FIG. 18. VERANDAH CAFÉ.

FIG. 19. GALLERY ON PROMENADE DECK.

FIG. 20. FIRST-CLASS SMOKING-ROOM.

FIG. 21. ENTRANCE TO GALLERY FROM MAIN STAIRCASE.

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(*For Description, see Page* 255.)

FIG. 22. RECEPTION AND BALL ROOM.

FIG. 23. FIRST-CLASS DINING SALOON.

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(For Description, see Page

Fig. 8. UPPER DECK "D"

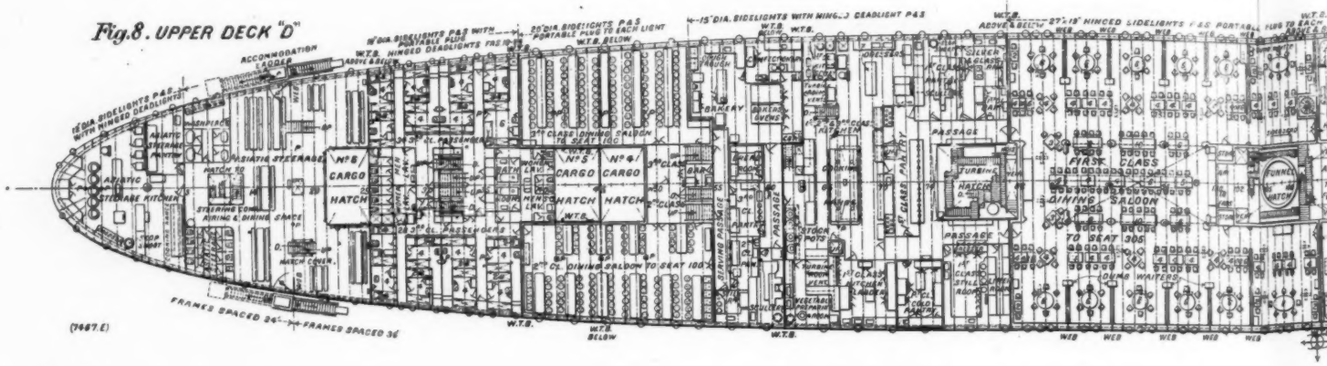


Fig. 9. MAIN DECK "E"

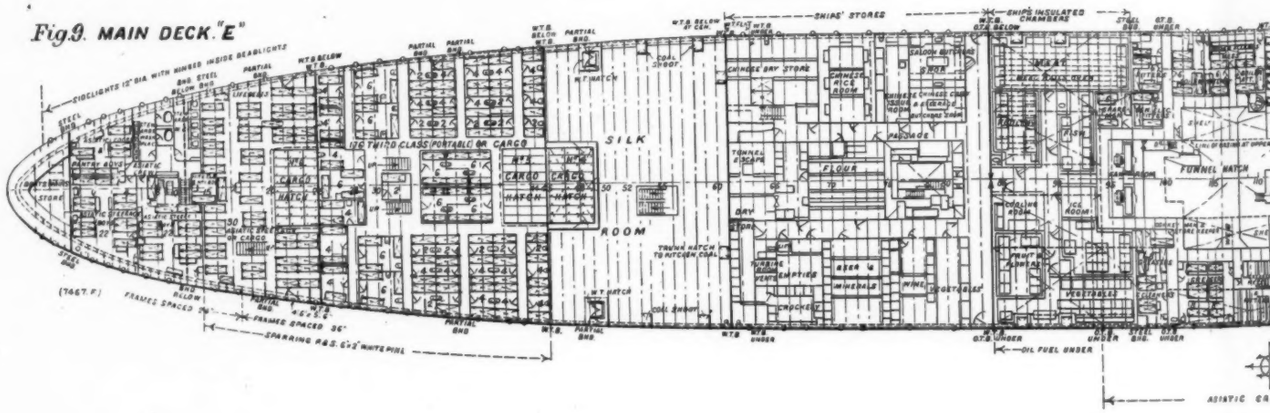


Fig. 10. LOWER DECK "F"

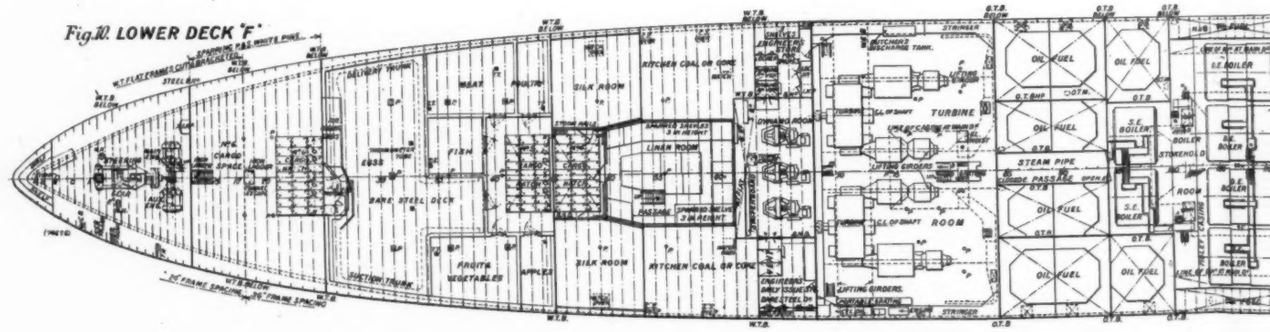


Fig. 11. ORLOP DECK "G"

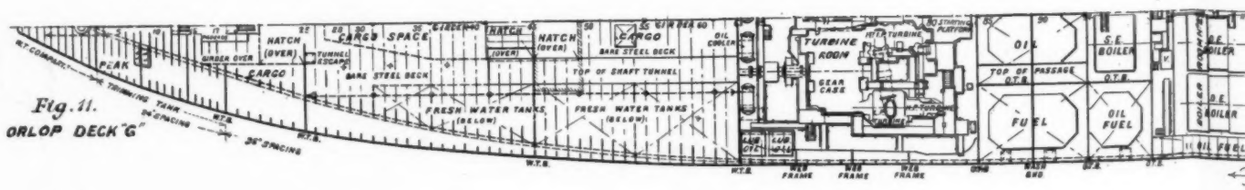
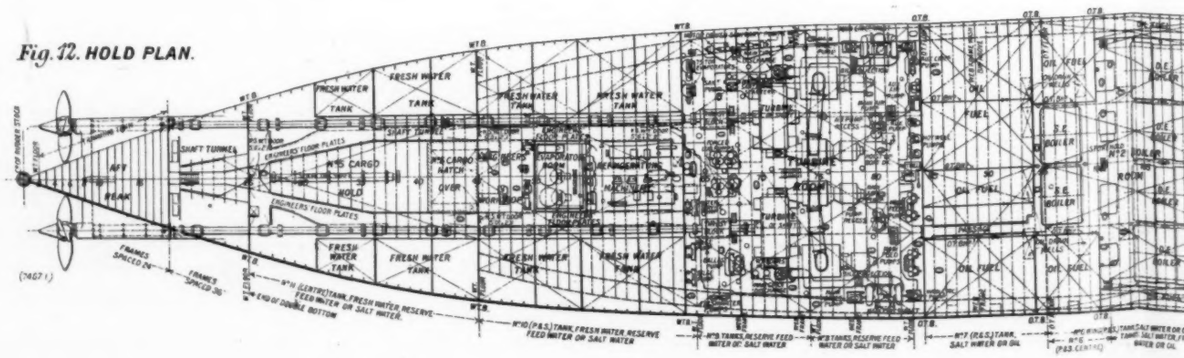


Fig. 12. HOLD PLAN.



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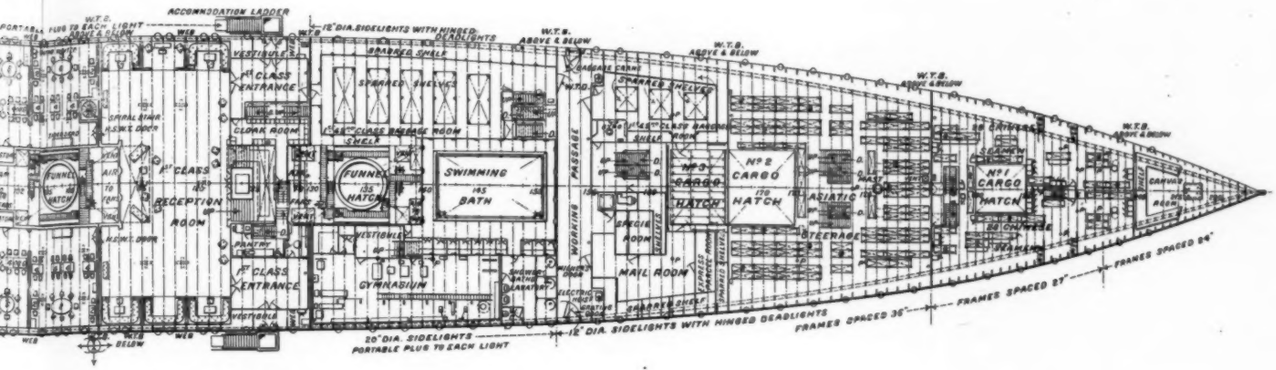

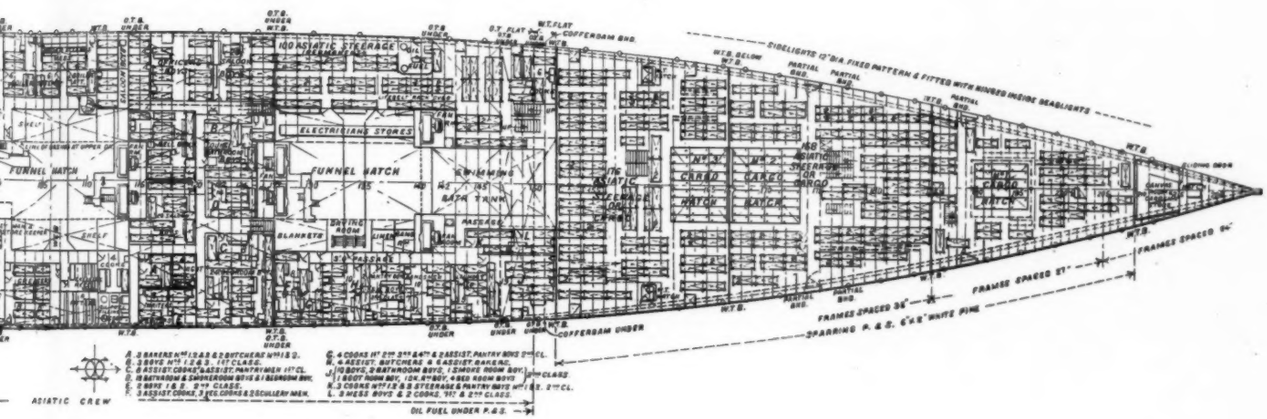

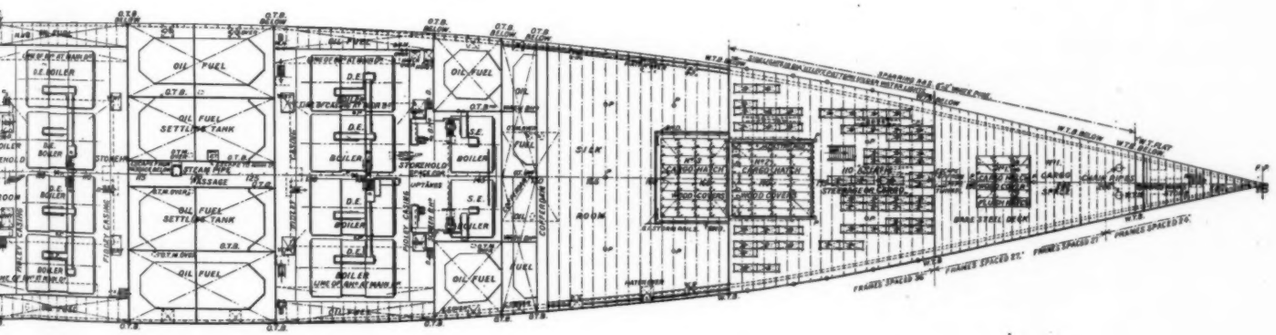

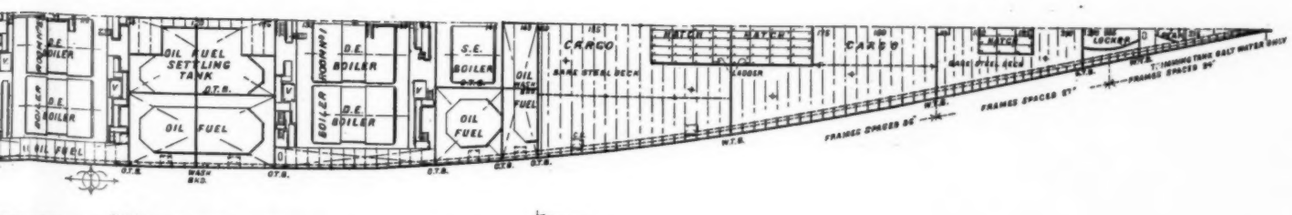

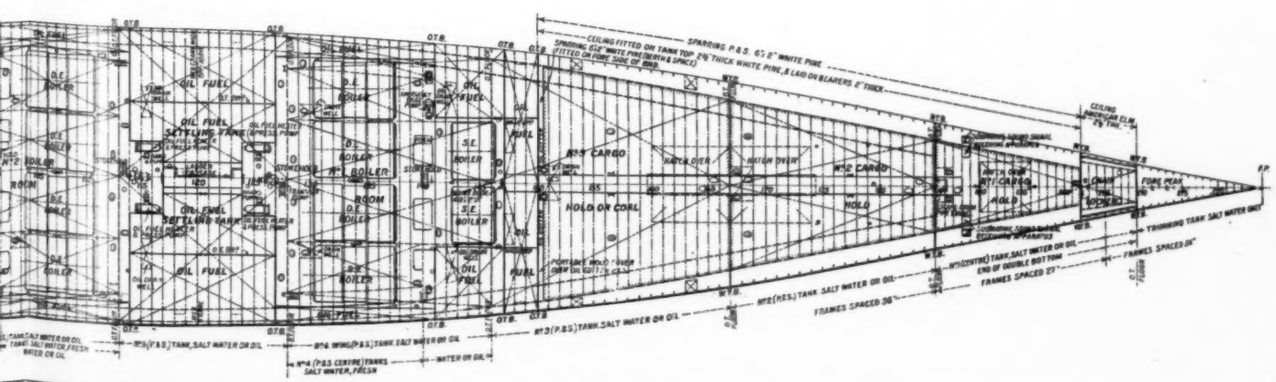
SPARRING P.& S. 6"x 2" WHITE PINE
SPARRING CEILING FITTED ON TANK TOP 2½" THICK WHITE PINE, 8 LAG ON BEARERS 2" THICK
CEILING FITTED ON FORE SIDE OF BHD.
OIL FUEL SETTLING TANK
D.E. BOILER
S.E. BOILER
No 1 CARGO
No 2 CARGO
No 3 CARGO
HOLD OR COAL
FRAMES SPACED 36"
FRAMES SPACED 27"
FRAMES SPACED 24"
No 3 (P.& S.) TANK SALT WATER OR OIL
No 2 (RES.) TANK SALT WATER OR OIL
No 1 (CENTRE) TANK SALT WATER OR OIL
TRIMMING TANK SALT WATER ONLY

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(*For Description, see Page* 255.)

FIG. 24. DRAWING-ROOM.

FIG. 25. WRITING-ROOM.

FIG. 26. SITTING-ROOM OF SPECIAL SUITE.

FIG. 27. BEDROOM OF SPECIAL SUITE.

FIG. 28. FIRST-CLASS TWO-BERTH STATE-ROOM.

FIG. 29. SECOND-CLASS LOUNGE.

(*To face page* 257.)

ENGINEERING.

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TIME FOR RECEIPT OF ADVERTISEMENTS.

Advertisements intended for insertion in the current week's issue must be delivered not later than First Post on Thursday. In consequence of the necessity of going to press early with a portion of the edition, alterations for standing advertisements should be received on the Friday previous to the day of publication.

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Two Two-Page Plates and Four One-Page Plates.—THE CANADIAN-PACIFIC LINER "EMPRESS OF CANADA."

ENGINEERING.

FRIDAY, SEPTEMBER 1, 1922.

MODELS AND FORMULAS.

MOST engineers would find themselves in agreement with the late Lord Kelvin in the view that a scientific theory is only intelligible to them when it can be represented by a mechanical model. Rightly or wrongly, we feel we can understand mechanisms whilst mere mathematical deductions, in spite of their practical utility and convenience, are never wholly satisfactory as an explanation of physical phenomena. De St. Venaut and Wantzel, for example, showed in 1839 by purely mathematical reasoning that the weight of compressed air discharged from a nozzle became a maximum when the external pressure was a little more than half the internal, and the result was confirmed by experiment. The mechanical explanation of the anomaly was not, however, given till some forty years later, when Osborne Reynolds pointed out that at the limit in question the velocity of efflux was equal to the velocity of sound in the fluid. Since any impulse travels along an elastic body with the speed of sound, it followed that once the issuing jet attained this velocity no further change in the external conditions could affect the conditions inside the reservoir, and hence the flow of fluid to the jet became constant once this critical velocity was attained. This interpretation of a mere mathematical formula in terms of mechanism was not only more mind-satisfying, but it showed clearly certain limitations of the theory, and also that it must necessarily apply not merely to the efflux of gases, but to that of liquids, the discharge of water from an orifice becoming a maximum when the effective head is about 70 miles. Any reduction of the external pressure, which would increase the effective head to more than this figure, would be accompanied by no increase in the weight discharged per second.

Whilst the interpretation of phenomena in terms of mechanism is that which appeals most to the engineer, it must be confessed that the hopes and anticipations rife in the last century, that the full attainment of this desideratum was merely a matter of continuing observation and experiment, seems doomed to disappointment. At one time certain sciences were classed as the "exact sciences," but to-day it would seem that mathematics alone can urge an effective claim to the title, and apparently its success is wholly attributable to the fact that, as stated by a well-known mathematician, "Mathematics may be defined as a subject in which we never know what we are talking about, nor whether the saying is true." The title of an exact science was at one time accorded to astronomy, and Hood, when he wrote in his familiar song that "The moon is constant to her time," merely reflected authoritative contemporary opinion. It is now known, however, that his testimonial was undeserved, and that there are some important discrepancies between observation and calculation.

There are other fields in which the mechanism we have imagined has broken down. It is not long since the corpuscular theory of light was reckoned as dead as the proverbial door nail; but in order to explain the electrical effects of light it has been necessary to resuscitate it, and we have the curious spectacle of scientific men holding simultaneously two mutually contradictory and conflicting theories, since in order to interpret interference in terms of mechanism it has been necessary to retain the undulatory theory when discussing purely optical phenomena. It has in this connection been suggested that the two distinct mechanisms in this case correspond to two different sections of the four-dimensioned continuum of the doctrine of relativity, just as a cylinder in one cross-section may be circular and in another rectangular. A somewhat similar condition of affairs is met with in connection with atomic structure. Thus, whilst the Bohr atom is apparently an efficient mechanism for interpreting radiation phenomena, it appears far less satisfactory as a basis for the discussion of the formation of chemical compounds, where a static rather than a dynamic atomic structure forms the more convenient model.

In short, whilst a couple of generations ago physicists had the hope that their theories were closely related to absolute truth, to-day they take the view so well expressed by Sir J. J. Thomson, viz., that "a scientific theory is a policy, not a creed." It is thus permissible to accept any model that helps us to interpret and co-ordinate observations and to push it as far as it will go. When it will no longer fit fresh facts a new start is made, but the old mechanism is retained in whole or in part and used for the discussion of such phenomena as it proves capable of interpreting.

This pragmatic view of a scientific theory is, however, comparatively new, and the older school of physicists certainly believed that their mechanisms were fairly representative of reality or, at any rate, only needed perfecting to become so. In one respect this view is probably retained, in effect, if not in profession, by the moderns. All recent evidence has served to confirm the truth of the atomic hypothesis, though our concept of the atom has changed greatly since Maxwell wrote his well-known article in the early seventies. Maxwell stated that individual atoms neither are born nor die, and that neither process was now in progress, the formation of an atom, being "not an event belonging to that order of nature in which we live," and is not going on "in the earth or on the sun or in the stars." It is interesting to contrast this view with the phenomena of radio-activity in which each ray emitted involves the death of one atom and the birth of a new one, and the final quotation is in direct conflict with the modern hypothesis that new atoms are being formed in the stars and in the sun, the heat of which is attributed to the energy liberated by the condensation of hydrogen neuclei into the neuclei of helium and other atoms.

Nevertheless, although the details of the atomic hypothesis have been materially changed since Maxwell wrote, the general theory is more firmly held than ever, and whether or no it actually corresponds to reality, it is of the utmost service in formulating and clarifying ideas. In practice we are given the choice of interpreting phenomena by means of a mechanism or of merely compactly representing the results of a limited number of observations by means of a formula. There is little doubt as to which is the preferable procedure, though it is not always practicable to adopt it. The questions with which an engineer has to deal are so complicated that in most cases an exhaustive

experimental study of them is precluded by questions of time and cost. This leads almost unavoidably to the formulation of empirical formulas, which may represent accurately enough the actual data available, but which are too often inherently irrational, and may lead to disaster if extended to conditions outside of the actual experimental range. When it becomes necessary to deal with such cases the engineer should reflect long on the physical character of the new problem, but too frequently he prefers to calculate instead of to think, and applies the old empirical formula with most unfortunate results. A few years ago it became necessary to construct a large steel cylinder, which was to be exposed to a moderate external pressure. The designer, though the conditions were far outside the range of his experience, fixed the thickness by means of Fairbairn's empirical formula for the strength of boiler flues, and as a consequence collapse occurred the moment the cylinder was exposed to pressure. This empirical formula was, no doubt, obtained in the first instance by logarithmic plotting, which is an expedient as dangerous as it is popular. Such a plot can generally be represented by a straight line for a considerable range of the variables, but is valid only within the range actually covered, and the resulting formula has in general no physical nor mechanical significance. Eaton Hodgkinson, for example, adopted this plan in devising his column formula, and obtained accordingly merely a mathematical expression, which though it represented quite well the experimental data, involved no hypothesis whatever as to how and why failure occurred. Gordon and Rankine, on the other hand, formed a mental picture of the nature of failure by crippling, and were thus able to propose formulas which were inherently far more reliable. The most flagrant abuse of this method of logarithmic plotting that we have come across was provided by a certain foreign professor of engineering, who, in reporting on the trials of a new turbine, plotted the logarithm of the efficiency against the logarithm of the ratio of blade speed to steam speed. In the range covered by the experiments the observations fell very accurately on a straight line, which was then extrapolated to deduce the efficiency at higher speeds.

Naturally anticipations thus arrived at failed to be realised. Such an absurd procedure would have been impossible to any one who pondered on the nature of the mechanism at work, in place of merely trying to find some sort of formula to represent accurately experimental data, which are of necessity inexact. The more closely the empirical rule fitted these inexact observations the less likely was it to correspond to the actual facts. The method is, however, a very popular one, and a laborious instance of it was provided by a paper on the properties of steam read some time since before the American Society of Mechanical Engineers. Here the author discarded all hypotheses as to the nature of a vapour, and by great industry devised a mere mathematical expression to represent as accurately as possible the inexact experimental data which were all that was available.

Rankine himself was not above criticism in this regard. Many years ago he gave a formula for the transfer of heat in boiler flues and the like, in which he made the heat flow proportional to the square of the temperature difference. Such a formula is inherently absurd, but Rankine justified it on the ground of its simplicity and convenience and its agreement with the experimental data available. The same procedure is still being followed in connection with this question of heat transfer. Formulas with no rational basis are devised to fit particular experiments and then found to be utterly untrustworthy when applied to slightly different conditions. Unfortunately, such a course is not always avoidable. The physical character of many phenomena is badly understood, and the experimental data cover but a short range of conditions. Logically no doubt it would be best in such cases merely to publish a plot showing the actual experimental results, but the temptation to find a formula to fit is commonly too strong to be resisted, and this purely empirical formula is then sometimes made the basis for theoretical deductions which are often wholly untrustworthy and at times involve actual absurdities. Such a formula has no doubt the convenience of being compact, but its value begins and ends here. Wherever possible, the form of such formulas should always be guided by physical considerations, and much help may often be obtained by resort to the theory of dimensions, which will generally show that certain relationships between the variables involved must exist. It is also a great advantage when the limits between which the law is required are strictly fixed by physical considerations. An empirical formula then becomes a formula of interpolation, and interpolation is always more satisfactory and accurate than extrapolation. An example is provided by the transmission of heat between a tube and a fluid traversing it at different speeds. Quite commonly the observed conductivity is plotted against the speed of flow, and hence for higher speeds of flow, extrapolation must be resorted to. If, however, the resistance to heat flow is plotted against the reciprocal of the velocity, it is known that at infinite velocity the resistance to heat transmission from the solid wall to the fluid must vanish, and we thus have fixed a definite point well beyond the limit of all possible practical conditions. Interpolation between this and the observations actually available is then a fairly safe procedure, though of course the rate of heat transmission is not a function of the velocity only, but involves also the viscosity and conductivity of the fluid and the diameter of the tube.

PATENT OFFICE REFERENCES.

INVENTORS will doubtless be aware that in those cases in which they have applied for patents the Patent Office often seeks under the present acts to insert at the end of their specification some reference to the prior art unless they can make abundantly clear the difference between what they claim and what has been done before. Important inventions very often reside in small points, and the difference on paper may not appear to be of substance. For that reason it is sometimes difficult to convince an examiner that there is a vital difference, and that one should not advertise prior patents by having references inserted to them in a later specification. There is less justification for this action since the Act of 1919 has come into force than formerly, because if anyone now wishes to know what patents were discovered by the Patent Office examiners in the searches which they made under the Statutes, he is able to obtain the information by making inquiry at the Patent Office in an appropriate manner and paying the customary fee. Specific references to prior patents have heretofore been inserted in specifications on grounds settled in published decisions of the law officers or the Comptroller, and broadly speaking it is found in practice that if a patent is of wide scope and embraces a new branch of industry, although it may be a limited section of a large industry, it is sought to obtain some recognition of this by means of a specific reference in a later application of other inventors. Heretofore it has hardly appeared to be material whether the prior patents had expired or not.

Recently an appeal was lodged to the court in connection with the revocation of a patent, and this question of specific references was discussed. It is most unusual for such a matter to come into the consideration of the High Court, because there is no appeal from the tribunal which ordinarily deals with specific references to the court. In this particular case, which is fully reported in the ordinary official reports on Patent, Design and Trade Mark cases, the matter which was mainly under consideration was whether the new grounds of opposition introduced by the Act of 1919 were available in a revocation proceeding in connection with an application which originated under war time legislation. The Comptroller declined to revoke the patent, but directed the insertion of specific references.

Mr. Justice Sargent, who tried the action, held that the amendment made by the Act of 1919 had not made the patent liable to revocation on any grounds more extensive than those on which it had been liable to be refused. This of itself is an important decision because doubtless many cases are likely to be in the same category owing to the large number of patents that have been applied for under war time legislation.

Further, he held that the specific references ought not to be inserted, first as to a patent of 1920 which was pre-dated, on the ground that it was not actually in existence in 1916, the date of the patent of reference, and so the insertion of a specific reference to it could not have been made a condition of the grant of the original patent of 1915. He held that specific references were not required in the other patents which happened to be in question for reasons which he explained.

Perhaps the more important part of his judgment from the point of view of inventors and the Patent Office is that it deals with the principles on which specific references are inserted. He gave, as his view, that it is more necessary that a person should be warned that it is not safe to use the invention than that a person should be warned that the monopoly rights are liable to some particular defect. In other words, this means that specific references should not be inserted with a view to advising the public that the subject-matter of an application is small in view of some prior patent, but that they should be principally inserted only in those cases where the public who seek to obtain licences under a later patent ought to be cautioned that they are liable to infringe some earlier patent still in force.

The learned judge stated that specific references ought not generally to be indulged in so much in the case merely of there being danger to the monopoly, as in the case of there being danger with regard to the safe user of the patent.

It may be that an appeal can be raised against the decision as a whole, but this does not appear to be clear. After discussion the judge gave leave to appeal if desired for what it was worth.

THE OPERATING RESULTS OF A MODERN POWER STATION.

UP to the present time estimates of the efficiency of large power stations have been much more plentiful than actual figures of performance. From a more or less accurate knowledge of what boilers and steam turbines can do under test conditions, engineers have had to estimate what a complete station could do under every-day conditions of service, and very few actual operating figures have been published which would serve as a check upon their calculations. There are two reasons for this reticence. One is the natural reluctance of many men to publish figures which, in the police-court phrase, might be "used in evidence against them." The other and probably the most general reason is that very few power station engineers themselves know with any accuracy the actual performance of the plant of which they are in control. The output is certainly known, but the vital figure of how much coal is burnt per kilowatt-hour of output can hardly ever be given except as a month's average, and an estimate at that. It is a discreditable fact that even the largest London stations have no means of weighing the coal to the boilers, or of measuring the water evaporated, and under such circumstances it is hopeless to expect useful figures of performance.

Among the few large stations which are properly equipped with weighing and measuring apparatus is the Glasgow Corporation Station at Dalmarnock, a full description of which appeared in our issues of May 27, June 10, 17 and 24, last year. The credit for the lay-out is due to Mr. R. B. Mitchell, the chief electrical engineer to the corporation, who gave some interesting figures as to its performance in a paper which he read at the recent summer meeting of the Institution of Electrical Engineers in Scotland. This paper we reproduced in full in our issue of June 2 last, as it was particularly valuable to station engineers as an example of the results which might be maintained by a large station under ordinary everyday conditions of working. It will be remembered that Mr. Mitchell emphasised the point which we ourselves have frequently maintained, namely that not only was it vital to economical operation to know both the amounts of coal consumed and of water evaporated on every shift, but that the

figures must be studied intelligently and compared shift by shift with a criterion of performance for the station. Only thus can any change for better or worse be instantly detected and the conditions looked into while the facts are fresh.

Mr. Mitchell explained that the method he had adopted at Dalmarnock was that devised by Mr. R. H. Parsons, which permitted a direct comparison to be made between the operating efficiency of different shifts, notwithstanding the fact that the differences in output would result in variations in the quantity of coal consumed and of water evaporated per kilowatt-hour. A diagram illustrating the method was given in Mr. Mitchell's paper, but this related only to fuel consumption in relation to output, and we are now able by Mr. Mitchell's courtesy to publish the full set of diagrams relating to the performance of the station over a period of four consecutive weeks. These are of unusual interest, for as we have already indicated, it is only too rarely that one can find a station where the operating results are exactly known, and where the resident engineer is willing to permit them to be published for the benefit of the industry generally. The diagrams in Figs. 1 and 2 above, and Fig. 3 on page 272, are to a great extent self-explanatory. In Fig. 1 the coal consumed on each of the 84 shifts which make up the period covered, has been plotted over the corresponding electrical output for the same shift. The output during the period varied from a minimum of about 30,000 kw.-hours to a maximum of over 230,000 kw.-hours per 8-hour shift, the aggregate output for the period in question being 9,784,000 kw.-hours. Through the plotted points a straight line has been drawn, the equation to which is found to be:

$$C = 20{,}000 + 1{\cdot}716\ K. \quad . \quad . \quad (1)$$

where C represents the number of pounds of coal burnt per shift, and K denotes the electrical output per shift.

From this equation, or from the line itself, the average coal consumption corresponding to any given output can be at once determined, and this when divided by the figure of output, gives the coal consumption per kilowatt-hour for that output. A curve showing how the coal consumption of the plant per kilowatt-hour varies with the output is plotted on the same diagram. It is seen that when 50,000 kw.-hours only are generated during an 8-hour shift, the standard coal consumption of the station would be 105,800 lb. for the 8 hours, or 2·116 lb. per kilowatt-hour. For a shift with an output of 200,000 kw.-hours the standard consumption would be 363,200 lb., or 1·816 lb. per kilowatt-hour, and so on. Both these consumptions represent equally meritorious performances, the difference in the number of pounds of coal burnt per kilowatt-hour being due entirely to the effect of the constant no-load losses of the station. The greater the output per shift the less significant, proportionally, do the no-load losses become, and the coal consumption of the station is obviously tending towards a minimum of 1·716 lb. per kilowatt-hour, which would be obtained with an output so great that the constant no-load losses were negligible on comparison. These constant no-load losses, as will be seen from the diagram, amount to only 20,000 lb. of coal per shift. This is remarkably low for so large a plant as Dalmarnock, for it must be remembered that this is the quantity of fuel required to make up all radiation and condensation losses in both engine and boiler-room and to keep the plant for 8 hours in a condition ready to pick up a small load without any notice at all. This implies that one turbo-generator would be running all the time fully excited at no load, and that the necessary auxiliary machinery would also be in operation. We shall return to this question later.

The second diagram, Fig. 2, deals with the relationship between the water evaporated and the electrical output. For the same 84 consecutive shifts, the water pumped into the boilers per shift has been plotted over the corresponding electrical output for the shift, in the same way as the coal was done in the previous diagram. The straight line drawn through the plotted points is found to have the equation

$$W = 100{,}000 + 11{\cdot}535\ K. \quad . \quad . \quad (2)$$

where W represents the total number of pounds of water evaporated per shift, and K the number of kilowatt-hours generated during the same period. A curved line showing the pounds of water used per kilowatt hour for any output as computed from the equation is also drawn on the diagram. It will be noted that the steam consumption of the station is tending towards a minimum of 11·535 lb. per kilowatt-hour generated, a figure which under the same operating conditions would only be reached when the output was so large that the no-load steam consumption was negligible in comparison. The no-load steam consumption is seen to be 100,000 lb. per 8-hour shift. It is assumed that the total steam consumption of the station is equal to the quantity of water pumped into the boilers, an assumption which in such a station as Dalmarnock must be very approximate to the truth, as water lost by blowing-down and otherwise will be negligible in comparison with that which goes to the making of steam.

From the two equations given, a third relationship can be deduced, which can be put in either of the two following forms:

$$C = 5{,}123 + 0{\cdot}1487\ W. \quad . \quad . \quad (3)$$

and

$$W = 6{\cdot}722\ C - 34{,}440. \quad . \quad . \quad (4)$$

The first of these shows that, if no water were to be evaporated, the coal consumption of the station would be 5,123 lb. per 8-hour shift, and the second shows that the greater the load on the station the more nearly the evaporation approaches the value of 6·722 lb. of water per pound of coal. The coal at Dalmarnock is analysed daily, and during the four weeks we are considering it had an average value of 10,500 B.Th.U. per pound. Taking the feed water temperature on entrance to the economisers as 141 deg. F., the theoretical amount of heat required to turn a pound of this water into steam at 274 lb. per square inch gauge pressure and 700 deg. F. temperature is 1,264 B.Th.U. This corresponds to 0·1204 lb. of the fuel used, so that the boiler plant is approaching a limiting efficiency of 80·92 per cent.

Returning to the question of no-load losses, it has been pointed out that equation (1) indicates that to maintain the station in a "stand-by" condition for an 8-hour shift would involve a consumption of 20,000 lb. of coal. If W were made zero in equation (3) the coal consumption during a shift would be only 5,123 lb. Making W equal to zero, means the evaporation of no water, so that one may deduce the fact that to maintain the boiler plant with regulator valves and junction valves shut, but with full steam pressure, and therefore ready to supply a small amount of steam at no notice, would require 5,123 lb. of coal per shift. This quantity of coal therefore represents the radiation and other heat losses in the boiler room, and the difference between 20,000 and 5,123, namely 14,877 lb. of coal, corresponds to the heat losses in the engine room. These include the no-load consumption of a turbine and its auxiliary machinery, the condensation losses in steam pipes, &c. The coal in question is indeed that required to

Fig. 1.

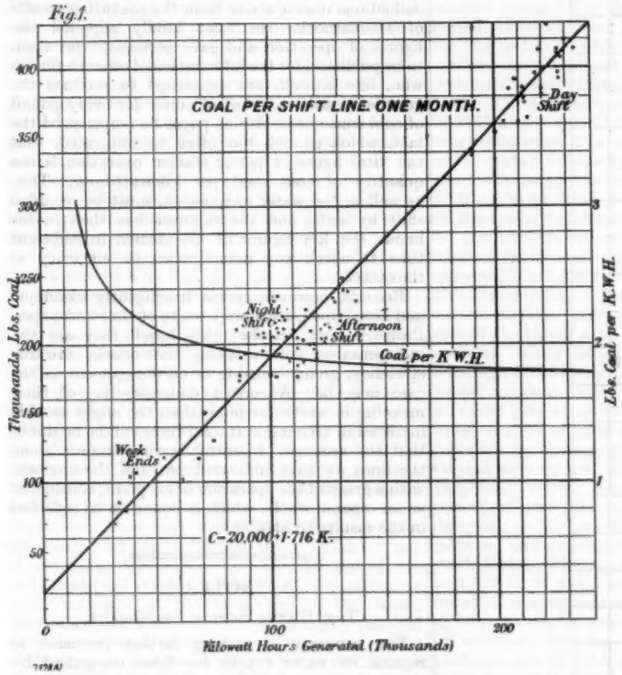
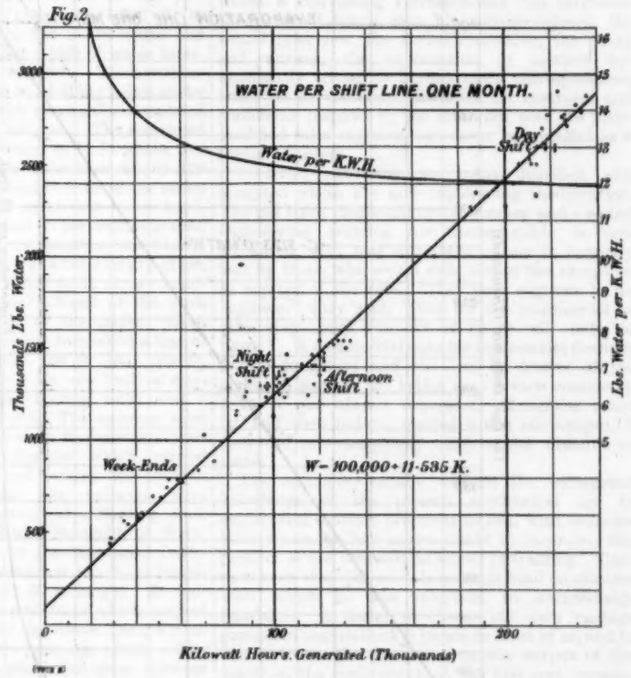


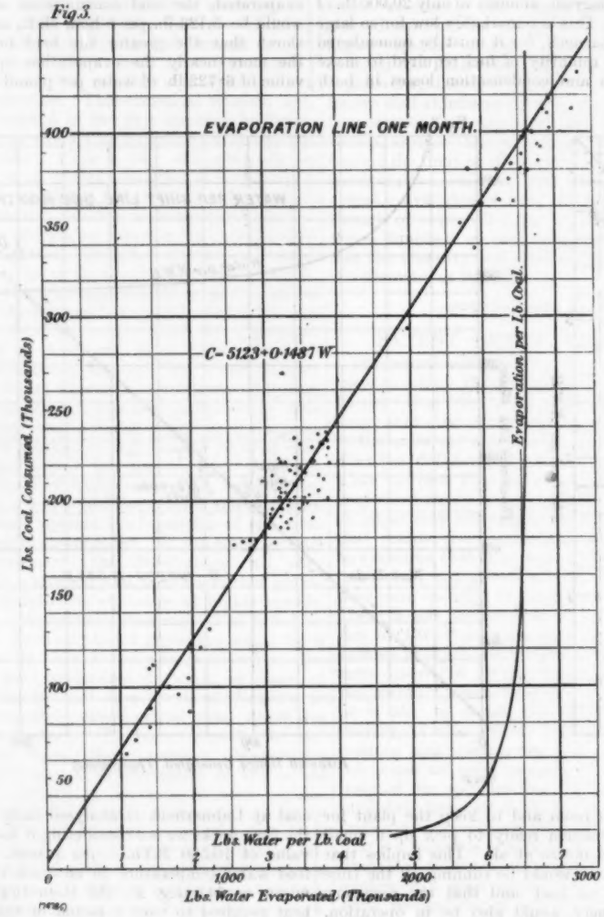
Fig. 2.



generate the 100,000 lb. of steam per shift which the station consumes at no-load, as seen from equation (2) and it effects this evaporation at the standard rate of 6·722 lb. of water per pound of coal. We thus have, by this method of analysis, a method of estimating with fair accuracy, the coal and steam consumption required to make good the stand-by losses of the station, and moreover we can apportion those losses between the engine-room and the boiler-room.

It may be objected that there would be in practice, so much uncertainty with regard to the exact position that the straight lines should occupy in Figs. 1 and 2, as to invalidate the conclusions we have drawn as to the constant losses. To determine the correct positions of the lines mathematically by the method of least squares would be theoretically possible, but the work involved would be altogether too stupendous to bring the method within the range of practical possibility. Nevertheless there are simple means of checking the accuracy of the lines drawn in Figs. 1 and 2. If these lines do not accurately represent the average performance of the plant at all loads, then equation (3) will not accurately represent the relationship between the coal burnt and the water evaporated. In Fig. 3, the figures for the coal and water per shift have been plotted for the same period as is covered by Figs. 1 and 2 and a straight line drawn by eye through them. The fact that this line has the same equation as equation (3) is strongly corroborative of the accuracy of equations (1) and (2) from which equation (3) was derived. There is, however, another way of checking equations (1) and (2). From the records of Dalmarnock power station, we know that 9,784,000 kw.-hours were generated during the period to which the equations refer. From equations (1) and (2) we can calculate the coal and water which would be required to generate such an output, the constants in the equations being multiplied by 84 in each case, because there are 84 shifts being considered. These calculations give a coal consumption for the period of 18,469,344 lb. and a water consumption of 121,258,440 lb. The coal consumption actually recorded was 18,481,568 lb. and the actual water consumption was 121,262,118 lb., so that the calculated figures are in agreement with the actual consumption within an error of 0·07 per cent. in the case of the coal, and within 0·003 per cent. in case of the water. As no power-station measurements can be commercially made with anything like this degree of certainty, the equations may be taken to be, for all practical purposes, absolutely accurate.

Fig.3.



Having justified the equations we may now briefly recapitulate the facts which may be deduced from them. In the first place it would appear that the stand-by losses at Dalmarnock are equivalent to the consumption of 20,000 lb. of coal per 8-hour shift. Of this coal 5,123 lb. are required to make up the losses in the boiler plant, and the balance of 14,877 lb. is consumed in making steam which does no useful work. Apart from the stand-by losses, every kilowatt-hour generated requires the expenditure of 1·716 lb. of coal and the evaporation of 11·535 lb. of water. These figures represent the coal and water consumption to which the station is tending as the output increases, and assuming no change to be made in the method of operation. The evaporation to which the station is tending is 6·722 lb. of water per pound of coal and a boiler-room efficiency of 80·92 per cent. is being approached.

The minimum amount of steam which the station would use, if it were merely standing by and ready to pick up the load without notice, would be 100,000 lb. per 8-hour shift. Furthermore, it is clear that if the constant of 20,000 lb. of coal is deducted from the total quantity of coal burnt on any shift, and the remainder then divided by the number of kilowatt-hours generated, the quotient will always be 1·716 so long as the station is operating at the standard efficiency. If the result on any shift works out either above or below 1·716, this shows that the efficiency of operation on that shift was worse or better than the standard efficiency by the same percentage. By plotting the results on a chart, on which a horizontal datum line representing 1·716 lb. per kilowatt-hour has been drawn, the relative efficiencies of the various shifts can be graphically shown. This, indeed, is the essence of Mr. Parsons' method of keeping a constant check upon the efficiency of operation, but we need not now enlarge upon it, because it was dealt with by Mr. Mitchell in his paper to which we have referred.

In conclusion we should say that Mr. Mitchell is not to be held in any way responsible for the deductions drawn above from the operating results of Dalmarnock. He most kindly supplied the figures of operation and gave permission for them to be published for the information of other engineers who, like himself, are concerned to produce the greatest possible amount of power for every pound of coal consumed. In his paper he emphasised the fact, which cannot too often be reiterated, that the vital figure in power station operation is the quantity of coal used per kilowatt-hour. This, as well as the water evaporated, must be recorded shift by shift, and the engineer has then in his hands the key figures of his station in sufficient time to check any deterioration in efficiency at the outset.

Records, however, unless intelligently examined and acted upon, are merely waste of time and paper. Properly used, on the other hand, they are the indispensable guides along the course towards efficiency, giving warning or encouragement as the case may be. A correct understanding of their meaning is worth far more than the slight trouble involved in arriving at it, and there can be no doubt that the analysis of central station records along the lines we have indicated provides the engineer with a grasp of the operation of his plant, considered as an organic whole, which is bound to be reflected in the results he attains.

NOTES.

THE WATER SUPPLY OF HOBART.

THE necessity of making further provision as regards its water supply has been recognised by the authorities of Hobart, Tasmania, for a good many years, and several reports have been drawn up on the subject at one time and another. As a result of a report submitted in 1921 by Mr. H. E. Bellamy, the City Engineer of Hobart, it was decided that surveys should be undertaken in the Lake Fenton district. The work which followed has now enabled Mr. Bellamy to submit a new scheme which presents advantages over those previously mooted. In a report just received Mr. Bellamy points out that previous schemes have suffered from the fact that they made no provision for increased storage, that the available water would be insufficient, the cost of long pipe lines required would be prohibitive, and so on. The Lake Fenton scheme now proposed, suggests utilising Lake Fenton and other available supplies in the National Park 50 miles from Hobart among the Mount Field ranges, and situated at a level of about 3,400 ft. above sea level. The park consists of some 38,500 acres of mountains and high forest lands and the rainfall of the district is about 60 in. There are proposals we understand to extend the area of the park. This ground would naturally form a catchment area little liable to pollution, while the use of the high level lakes would tend to maintain the supply in a state of purity. The present scheme involves works at Lake Fenton, including outlet head works capable of drawing off water at 40 ft. below the normal water level, pipe line head works at Lady Barron Falls, three balancing reservoirs with connecting inverted steel syphons, and other works. The total length of the

aqueduct would be 54 miles, and the diameter proposed is 24 in. for 14 miles on a grade of 1 in 400, and 27 in. for a 40 mile length at 1 in 750. The actual catchment area for the Lake Fenton scheme would be over 12,000 acres. Later on it would be possible to increase the capacity of the scheme by means of a 20 ft. dam at Lake Fenton, and 20 ft. weir and control works on the Humboldt Valley. The cost is estimated at 660,100*l.*, but promises a far better return on expenditure than previous schemes.

OILINESS AND THE MECHANISM OF LUBRICATION.

In giving an account of researches, which were subsidised by the General Motor Corporation and the Standard Oil Company, on the "Mechanism of Lubrication and the Methods of Measuring Oiliness," Robert E. Wilson and Daniel P. Barnard, of the Massachusetts Institute of Technology, define oiliness as that property of lubricants, by virtue of which one fluid gives lower coefficients of friction (generally at slow speeds or high loads) than another fluid of the same viscosity. That definition (*Journal of Industrial and Engineering Chemistry*, August, pages 682 to 695) does not advance matters much, and we do not think that the importance of oiliness—the ability of a very thin, probably semi-fluid film of the lubricants to adhere to the metal surfaces, in spite of the pressure and the abrading effect due to motion, as they subsequently put it—is so insufficiently recognised as they assert. But some of their experiments with the Deeley oil tester of 1920 and with a static friction tester, as well as their attempts to measure the film thickness are novel, and their conclusion is somewhat unorthodox. In their static friction test they use a loaded slider, a spherical segment generally made of speculum metal (the hard, almost incorrodible alloy Cu_4Sn) gliding on a plane of steel, highly polished like the slider, and inclined at variable angles. The static friction coefficient, they find, is always higher, especially with glass surfaces, than the kinetic coefficient, and the static test affords the best means of estimating the oiliness which is increased by adsorption into the metal surface of certain constituents of the lubricants. They dispute the fairly common assumption that low interfacial surface tension and low friction go together; there is no direct connection, they say, and friction depends upon the nature of the adsorbed layer which is not of molecular dimensions, but colloidal and plastic and semi-solid rather than fluid. To arrive at some estimate of the thickness of the layer, they place two steel cylinders with highly-polished faces in a trough, bring them into contact under slight pressure and insert them into one of the arms of a Wheatstone bridge. The contact resistance was first determined in air with the cylinders wrung together; the faces were then separated, the trough was filled with the oil under test, and the cylinders were forced into contact again. This operation, separation—which would partly destroy any oil film formed—and restoration of contact, was repeated several times at intervals for 24 hours; during the first 6 hours the resistance increased rapidly, then generally very slowly, rising finally to about 3 ohm from 0·03 ohm initially. We are doubtful whether these experiments really demonstrate increasing film thickness. Weak direct currents were used in the measurements; when alternating currents were finally superposed (or strong direct current used from the beginning), the resistance dropped nearly to zero. That rather seems to suggest heat and chemical effects and polarisation; the film would be very thin in any case, and the electric resistance is exceedingly sensitive to slight polarisation. Actual thickness estimates are not given by Wilson and Barnard. Further to prove the surface adsorption they stirred the oils—which were mixed with fatty acids as in the other cases—with various pyrophorous metals, iron, &c.; the friction coefficient increased because, they say, the large surfaces absorbed the active constituents; but the strong chemical action of the pyrophorous metals, reduction of the fatty acids, does not appear to have been taken into consideration. On the other hand, Wilson established that oils adhere in thicker layers to the walls of capillary tubes made of glass than to the walls of tubes made of magnesium, brass, steel and iron. They forced oils through capillaries of these materials under equal conditions and they found that the rate of flow diminished in the order stated.

PORT EXTENSIONS AT KOBE, JAPAN.

An important part of a large extension programme at the port of Kobe in Japan has just been completed. The first section thus finished is being followed by a second of almost equal importance, while still another is planned. The work now brought into use consists of three double-sided and one single-sided jetties, protected by a length of breakwater which forms only part of a longer stretch ultimately planned to enclose a water area sufficient to serve for all extensions for some time ahead. The work was originally started in 1907 with the reclamation of foreshore. As a result of the requirements of the war the work was expedited considerably, but it was necessary to cope with the volume of business to adopt temporary measures, since discarded in favour of the permanent plans. The four moles are 1,200 ft. in length, three of them being 336 ft. in width and the fourth 180 ft. wide. The width of water intervening ranges from 480 ft. to 540 ft. The foreshore reclamation necessitated 20 ft. of filling below water level. The reclamation work was finally completed in 1921 at the cost of 518,858 yen. The reclaimed area represented 65 acres raised to 11 ft. above low water spring tides. At the same time about 270 acres were dredged between and in front of the moles to from 30 to 36 ft. below mean low water level. Of the dredged material about 60 per cent. was used for the lower layers of the reclamation, sand being adopted for the upper part. The total length of the quay walls is 9,556 ft., of which 8,172 ft. are available for shipping. The chief interest of the work centres in the construction of the moles. Each side of the three main moles is formed of a line of caissons. Each caisson was 120 ft. long, 35 ft. 6 in. high and 34 ft. wide. These were built of reinforced concrete with thin tapering walls and a 4 ft. toe projecting all round. The caissons were built on rows of piles placed 15 ft. apart and surrounded by permanent wharves which carried staging moving on rails and serving for erection purposes. When complete the caissons were picked off the piles by means of a floating dock designed by Messrs. Clark and Stanfield, of Westminster, and constructed at the Kawasaki Dockyard, Kobe. This dock measured 145 ft. in length and 137 ft. in width and 51 ft. in height. It consisted of one vertical side wall from which project eight pontoons, attached to the whole being a float or outrigger carrying the pumping plant. The pontoons are 10 ft. 6 in. wide, the space between them being 4 ft. 6 in. wide. In operation the pontoons are partly filled, and the dock is then moved so that the pontoons pass between the rows of piling on which the caissons are built. The pontoons are then pumped out and the caisson thus lifted. The dock is then withdrawn from the building wharf and sunk, and the caisson floated to site. The caissons were sunk 6 in. apart, this space being later filled in with concrete. The single-sided mole consists of one line of caissons and back filling with concrete block protection from the sea on the other side. The moles are all fitted with steel sheds, 18 in all, with a floor area of 539,451 sq. ft. The span is uniform and 84 ft. Two wooden sheds were also built. The cranes on the wharves vary from 1·5 to 5 ton capacity, there being fourteen of the former and seven of the latter, serving the seven quays. The total expenditure on the caisson construction between 1911 and 1918 amounted to 2,825,400 yen; this includes mooring posts, bollards, &c. The cost of the sheds was 2,616,210 yen, and of the cranes, including one of 30 tons, and four fixed 5-ton cranes, was 650,306 yen. The total expenditure contemplated in the whole improvement scheme is over 41 million yen.

FOREIGN POPULATION OF CHINA.—Notes which are issued by the Bureau of Economic Information, China, contain a table stating that there are in that country 9,511 foreign firms and 240,769 foreign inhabitants. Some of the detail figures are as follow:—Japanese, 6,141 firms and 144,434 inhabitants; Russian, 1,613 and 68,250; British, 703 and 9,298; American, 412 and 8,230; Portuguese, 152 and 3,493; French, 222 and 2,453; German, 92 and 1,255.

ENGINEERING SALESMANSHIP.

By A SALES MANAGER.

INTEREST is again being revived in the vexed question of engineering and commercialism. The slump which succeeded the unprecedented demand at the conclusion of the late war has directed the minds of most firms to the sales side of their organisation. It is being realised more and more that a successful business is not built up and developed solely by the sterling quality of the goods manufactured. Neither will advertising in trade and general periodicals alone give the desired results. With comparatively few exceptions most of the engineering firms of this country have failed to appreciate with adequacy the importance of mobilising and training a thoroughly efficient sales corps, one befitting the dignity and reputation of its business.

Whilst modern publicists can convey individualism if not a little personality by an advertisement, and whilst a convincing correspondent can introduce the personal touch into his correspondence, the actual interview, the verbal discussion, the query and answer, the explanation of matters too apparently trivial to burden one's correspondence with, yet nevertheless influential, the assurance and confidence inspired by the interview with the fully-qualified sales engineer can never be equalled as a source of orders.

Certainly old ideas are being dispelled, and accepted views are now undergoing modification. The old tenet that commercial acumen and a sound engineering training are incompatible is now advanced with less dogmatism than it formerly was by those who would only accept the exception as a proof of the rule. "Let your engineer be an engineer," they said, "but for the commercial or sales side—keep him out of it, he will only do harm." A commercial man for commercial dealings and negotiations and the less he knows of the technical matters the better, was a view commonly held, if not always expressed. Examples could be, and were indeed, quoted which encouraged, if they did not completely confirm this attitude of mind.

The customer, usually without the widespread knowledge of the present mechanical age in engineering matters preferred to deal with someone with whom he had more points in common—the product of the commercial school of training. One, moreover, who did not talk over his head on matters with which he was reluctant to acknowledge ignorance. A desire to choose our own vantage ground in negotiations is innate in most of us, and to the customer the discussion on the output of the machine, the space occupied, the first cost, running costs, delivery date and terms of payment were (and still are, of course) vital matters which he could intelligently and advantageously discuss with complete freedom from the cross-currents of actual and detailed construction of the machine likely to be discussed at length by the engineer. The technique of design *per se* was likely to confuse the issue even if it were not a distinct boredom. A competitor's price and terms of contract were finite and familiar matters which could be handled to advantage, and which could be wielded as useful sparring weapons. On the other hand a purely technical analysis of the designs disarmed him and left him impotent.

The watertight compartments of the sales and design sides discouraged, if they did not entirely preclude, the opportunity of acquiring the necessary commercial experience by the technical engineer. The ranks of the commercial staff were recruited from the clerical side and were given the necessary training and experience. The success they gained was, and could be, taken as a justification of the procedure.

Conditions have changed rapidly during the last generation. Nowadays, for instance, ignorance in connection with the standard elementary mechanism of motor cars is even amongst laymen sufficient to rank one as an "outsider," and it is, if anything, looked upon with as much intolerance as is an ignorance of golf. The motor car is mentioned because probably more than all the other influences combined it has been instrumental in inculcating a study and an appreciation of mechanism in the

minds of the larger portion of that section of the community to whom the engineering salesman can look for his potential customers. As a necessary corollary a nodding acquaintance of this particular branch of engineering is expected in any sales engineer.

The continued increase in the development and application of machinery to all branches of industry, its wonderful capacity for increasing, regularising and standardising production, the educating and enlightening effect of the preponderating mass of engineering appliances and munitions of warfare used in the late world war—all these have had their effect in arousing the mechanical instinct which lies dormant in so many of our countrymen.

To-day, then, your engineer salesman must know his subject. For very self-respect he must be able to discuss any point of design in his production, and must show no less a knowledge than his prospective client, if he is to engender that confidence which is of prime importance in influencing subsequent orders. The more he knows as to the application of his product to his client's industry the better he is able to emphasise and demonstrate those features which are likely to appeal.

An intimate knowledge of the salesman's competitors' productions is invaluable—not as a text to preach their demerits, the folly of this is admittedly trite to-day, but as a useful guide in indicating the particular features of his own design where transcendency is in evidence. The really successful salesman can by tactful implication score over his competitor without in the least advertising him. Even in these days of intensive advertising and publicity propaganda it does sometimes happen that the first intimation of the existence of a real competitor comes from the lips of an enthusiastic but indiscreet salesman in his attempt to depreciate such a competitor's productions. The result has been that competition has been induced where otherwise there would have been a more or less *carte blanche*. It is unnecessary to say that such cases are rare, but they are far from being non-existent.

It is regrettable that salesmanship is viewed by many as that of the bagman type of commercial traveller who may be selling anything from sticking plaster to ladies' blouses. It is also often falsely conceived that the main qualifications are those of a brazen face, an ingratiating smile, an excess of plausibility, if not a total disregard for truth, a penchant for funny stories and a never failing "What's yours?" Whatever the qualifications demanded in the Knights of the Road may be for the sale of the goods mentioned, and quite possibly they are stringent ones, the successful sales engineer will need a much more comprehensive and intensive education and training. He should realise that as his firm's representative he will be expected to be truly representative of his firm, and to a large extent his firm will be judged for good or for ill by the technical advice he is able to offer, the influence which he creates, the impression he is able to convey and the manner in which he comports himself.

The ideal salesman must have commercial acumen, he must thoroughly understand human nature in all its manifold phases, moods and diversifications. A sympathetic well-controlled personality free from mannerisms and affectation, the possessor of indomitable energy, restrained tenacity, unquenchable enthusiasm in his pursuit, are only a few of his requirements. Whilst courses of training in schools of salesmanship can do much to drill, discipline and sharpen faculties lying more or less dormant, they can never take the place of native wit, the complete understanding of human nature and correct assessment of the individual point of view. An interview can seldom, if ever, be rehearsed with advantage. The salesman may intend to direct the course of the discussion, but usually it is the prerogative of the buyer, who also usually exercises it, and the wise salesman is he who realises the advantages to himself of such a course.

The hardest "nut to crack" is the silent buyer. With closed lips and a countenance expressive of nothing but tiredness and incredulity, a monosyllable at the most here and there—this type is warranted to chill the most enthusiastic and genial, and to turn eloquence into vain mechanical speech. Audacity has been employed successfully by not a few dealing with this type—a brazen suggestion that he is there to place an order, and you are there to book it—"How many?" or "What size, had you to book," has prefaced any description or examination into the merits of the commodity. Audacity can be employed in numerous directions, and what would be acceptable in one case would be treated as a sheer impertinence by many buyers.

It is extremely difficult to give illustrations which bear even the semblance of authenticity. One calls to mind the invariable rule employed by one salesman in negotiating the sales of power plant to such a reticent buyer as the one described. After the usual exchange of courtesies during which he sized his man, he would make some such request as "Now can I see where you are going to have this plant of ours (or yours) fixed?" Usually the request was granted and incidentally the buyer's views and a hearing for the salesman were obtained through the medium of a discussion on ground space, foundations, question of drive, &c.

It will be realised what an immense advantage an engineer salesman has over the purely commercial bagman in such circumstances. In passing, through the client's works or factory the former notices with keen interest any machine, mechanism or engineering device worthy of a compliment, throws out a suggestion where an obvious improvement could be effected (whether in his own particular line of product or not), or even asks a sensible and discreet question or two about the methods of manufacture, the labour problem, the finished product or raw material, thereby touching on matters of paramount interest to the prospective customer. Many times has a frigid non-commital buyer been intrigued, and an order obtained by some such line of action as this, and provided that the salesman has been an engineer with good general engineering training he has subsequently been received in the status of a consulting engineer.

It is fairly safe to argue that such buyers are in the main more valuable in the shape of connection than the more easily approachable type, as once they are secured they are more easily retained by their very virtue of freezing off the average salesman. To those who have the highest-grade article to sell the buyer who shows a disposition to discuss nothing but price is the *bête noir*. Every argument, every point of superiority of either design, workmanship or material is met with the remark "I know all about that, but the price!"

It is a comparatively simple matter to give things away, and salesmanship would not have that valuable function which it possesses if everyone bought and sold on price alone. The postman would do the work just as effectually and at the lowest cost. Here, again, the engineer's technical and practical knowledge is called in. To be sure the commercial type can argue in platitudes. A good article is worth a good price and a better article a better price, rubbish is dear at a gift, &c., but when it is realised that the buyer himself has to convince in turn his principal, whether it be the private owner of the factory or the Board of Directors, or the Committee of the Corporation, or other public body, and that they will argue exactly as he is doing, then greater effort is required on the part of the salesman to describe in the language and method most likely to be understood and grasped for further exposition by the buying agent. Obviously, an exposition on involved thermodynamics would be misplaced energy if dealing with an engine buyer to whom such matters were a mystery. The engineer salesman must by intuitive evolution find out the limitations of his client's knowledge and argue accordingly. It is far better to drive home one or two salient points than befog a buying agent who has a limited knowledge and who, moreover, has to carry in his mind the other competitors' claims.

There is a laudable feeling of self-congratulation, if not exultation, in having secured a highly competitive contract on the highest price tender, whilst there is usually cause for self-congratulation if the only complaint or criticism and the reason for non-acceptance is one of higher price rather than that of defective design, material or workmanship. Whilst one can never feel gratified at loosing a contract, it is much more hurtful to one's pride to find that the reason given is that of inferiority, which in the buyer's views is not counterbalanced by the lower price.

Commercial acumen can never be initiated in the drawing office, not can it be developed in the works. The only training ground is the great school of commercial life. Your candidate for salesmanship must obtain an intensive practical and technical experience in engineering, but should go out into the world's mart before he becomes atrophied. His perspective will be adjusted and trued, and his mind will be receptive to the many lessons he will learn and unlearn.

If he is sent out in connection with definite inquiries he will not have the more numerous rebuffs which the ordinary canvasser has to meet. The latter has a much harder task, but given the native attributes the lessons are the more valuable. Day after day he is combatting an atmosphere which, if not offensively hostile, is at the best indifferent. He learns the extreme value of individuality. This quality and all that it implies will, if fostered and developed, rank as his main introduction. He also learns the importance of adaptability and sympathetic tolerance.

He will probably be surprised to find that his firm, whom he had always considered, and rightly considered, to be all-important, is quite unknown by many of those on whom he calls. His knowledge of the right man to see—the buyer— will be strengthened. The extension to him of excessive courtesy by those who have no influence on the placing of orders will be appraised at its true value, and he will learn that several rebuffs and an eventual order from one buyer are worth more than innumerable pleasant receptions as entered in his reports. He will be astounded at what he considers to be the short-sighted policy of large and important firms in delegating to a mere commercial man, without engineering experience, the discussion and purchase of engineering productions. Incidentally he will learn to suit his text to his hearers and discriminate between treating their intelligence as that of either babes or post graduates in his own particular line.

That there is nothing so human as human nature will often be brought home to him as his views are broadened and ripened. A cheery, optimistic outlook on life, an up-to-date touch with everything which interests the average man, sports, hobbies, music, drama, these will be found to be influential in their correct focus, and much more desirable than the ostentatious parade of recondite theories with a view to impressing the buyer with the depths of his knowledge and learning.

At the same time, and lest it should appear that the social side is all-important, it must be recognised that however it may apply to some branches of commerce, in engineering at any rate, a salesman cannot know too much of his subject. Every process and stage of manufacture, the outlines of every test and inspection of materials and workmanship, the present trend of invention, research and development, and the many varied conditions of application, all these should be mentally docketed in his armoury, not for a parrot-like recitation or gramaphone record, but for reference when some question is asked or a remark made which justifies their mention.

As he travels about, the salseman engineer will see variations in the conditions and methods of application of his own firm's and competitor's productions quite outside the conception of the inside man. Local conditions here, the peculiar requirements of some branch of manufacture there, or the ineradicable prejudices of a consulting engineer elsewhere, all tell their own story and teach their own lessons, lessons which influence design, manufacture and the cost of productions, and lessons which are of appreciable value to the sales engineer both directly and indirectly, inasmuch as this acquired knowledge is of the greatest interest to his prospective customer, who is primarily interested in the methods of application.

From this particular standpoint of an engineer salesman's opportunities and training, it might be seriously advocated that no one should be appointed to a really responsible position in design unless or until he had gone through a course "on the

road" preferably with remuneration based on results. Such a proposition is put forward not with a view to inviting the acclamations of the many sales engineers who have wearied in their countless and unheeded reports to head office on the necessity for alterations and amendments in design, but as a serious suggestion by one who in design has profited beyond conception by those who have lacked the opportunity. The market price is a vital factor, and this price is fixed with some little approximation by one's competitors and the users. In the absence of a complete acquaintanceship with the manifold and specific requirements of the customer, and unless one be a mere copyist, there is risk in the designer unconsciously depending on either his firm's good will or the personality and influence of the salesman.

Both these are realisable assets up to a point, but sound business policy would be to treat them as concomitants to the purely intrinsic value of the goods.

Salesmanship in engineering productions cannot be carried out efficiently either by a member of the clerical staff or by the man who has merely gained social distinction. The sales manager of any medium or large firm must not only be a front rank salesman, but he should be able to choose suitable raw material and train and develop likely and promising recruits. In constant touch as he is with every outpost in the field by report and periodical visit he can be of inestimable service to all the other branches of the business. Each new design or modification, each change in policy by the Board of Directors, in short, everything bearing on the commercial aspect of the business should be submitted to him and his views invited.

He should be given within reason full discretion in the final settlement of the contract price, and he should possess a sufficient layman's knowledge of commercial law to inaugurate or amend specifications and terms of contract. His previous sales experience as an individual sales engineer or branch office manager will befit him for appreciating the difficulties with which his staff are likely to meet, and the possible tendency of laxity arising. A large contract should demand his personal attention, and a branch office will only be too ready to appreciate his assistance.

For foreign and colonial trade much the same attributes are required. Perhaps a little more imagination is called for. Inquiries from every corner of the world are as diverse as oft-times they are brief. It is necessary, therefore, that one should be able to picture and reconstruct the position of the client in order to quote successfully. It seems idle to suggest that out of 10 tenders from different firms the customer will naturally be prejudiced in favour of the particular one which is a covering letter showing a conception of his special requirements by anticipating and elucidating any little difficulty in his mind. There is a tendency in connection with foreign inquiries to regard them in the shape of a lottery. Many are in the nature of events purely idle inquiries, in time one can almost sense them. The simplest method of dealing with them is to write formally acknowledging receipt and enclosing a printed specification, tender mainly printed, with a few blanks for type-written figures, accompanied with an illustration or possibly a pamphlet. If the customer's requirements cannot be met with exactitude then the nearest unit with respect to size and capacity is quoted for without possibly a word of explanation. In other words, unless the customer has previously made up his mind to purchase from such a firm irrespective of competitive quotations he is chilled with the apparent indifference exhibited by such a cold, formal, lifeless and soulless response.

The antithesis of this method is that in which the inquiry is treated by one who realises that as far as the inquirer is concerned this is the most important query likely to be dealt with in this particular year. If it can be conveyed to the customer that out of the manifold inquiries received, this is the one for which their product is peculiarly applicable and adaptable, and if further, one or two interesting facts relative to other installations in the same particular line of the customer's business can be briefly referred to—so much the better. Business, particularly foreign business, is based in the main on confidence, and unless confidence can be engendered in the customer's mind little or no business will result.

Moreover the inquirer may, and actually does, argue that "if this is an example of the interest displayed towards me in my inquiry, what sort of treatment am I likely to receive if after negotiations have matured and I receive delivery, some unforeseen defect or difficulty arises prejudicing the profitable use of the apparatus or plant."

This phase has been put to the writer by clients in all parts of the world, and keen as the foreigner is on price he is usually disposed favourably towards the firm who fully appreciate his importance to their interests, and to whom he could apply with confidence for advice after the contract has been closed and payment completed. It may be argued that foreign agents are appointed by all large engineering firms for just such cases as these, but usually such agents represent perhaps a dozen different firms in a dozen different trades, and it is absurd to expect a foreign agent to understand the technicalities even of every branch of engineering, let alone the other diversified lines he is handling.

Again, such large engineering firms are extensive advertisers, and often times the foreign customer is influenced by the reputation of the parent firm rather than the integrity of the foreign agent, even if the latter be one of his own countrymen. Obviously then he is more favourably impressed by communications from the head office or works particularly when they exhibit an intelligent appreciation of his technical difficulties, and he will be more favourably disposed towards both the agent and the parent firm, knowing that whilst free to arrange financially with the former he can rely on the latter for technical advice and guarantees of efficiency. If such foreign communications are written in a foreign language it is of more than complimentary value to reply in the same language. Lest it should be imagined that a sales manager's qualifications are already impossible of fulfilment in any one individual, linguistic translations can be handled by a foreign correspondent, who can convey the personal touch introduced in the draft reply.

On the social side the sales engineer should be cosmopolitan in tastes and versatile in interests. He need not be a brilliant conversationalist; a sympathetic listener will book more orders than a mere gas bag. Whether dealing with belted earl or a more humble member of society, he should be able to invoke an atmosphere of easy tolerance, in short, he must just be a gentleman. The day is happily now long past when the placing of an order was accompanied by the imbibing of an inordinate quantity of liquor, and to-day even a teetotal sales engineer would not find his success prejudiced materially.

The occupation demands considerable sacrifice. At a moment's notice one must be prepared to make a railway journey involving absence from home for an indefinite period. There are very few lines in engineering which accommodate themselves to a set round of periodical visits fixed some weeks ahead, as in other commercial lines. Many evenings have to be sacrificed by the sales manager in entertaining customers who are visiting the works from distant parts.

If he has travelled extensively on the Continent and received the never-failing hospitality so lavishly bestowed on a Britisher he will feel constrained to go to some considerable trouble and personal inconvenience in extending to his foreign clients those amenities most likely to be appreciated. At the best ours is considered a dull country by the Continental visitor, but he is neither ungrateful nor unresponsive to efforts put forward conducive to his own comfort and pleasure. Good address is a necessity; good appearance, so essential in a shop walker, is of minor importance, but not entirely negligible. Dimensions taken from the chin upwards are more reliable data than 6 ft. of inertia, Adonis had not served his apprenticeship in the foundry and the shops.

In deploring the lack of candidates for this most important branch of engineering—a practise which is to-day again rife—it must be admitted that there is no shortage of raw material in this island of shopkeepers of ours. Lack of opportunity and the undoubted prejudice which exists in the mind of the college professor and professional man against any possible tainting of the profession by commercialism coupled with the prejudice of the purely commercial managing director, or board of directors, against the claim of the engineer's possession of commercial attributes, are the prime causes of the paucity.

It has already been suggested that the aspirant should be sent out into the broad highway before he becomes atrophied. Granted that his curriculum is already sufficiently comprehensive, a few journeys will demonstrate to the experienced and discerning sales manager his potentialities, and a few experiments by trial and error in the earliest stage will fully repay the necessary sacrifice involved.

There is some conflict of view on the question of the best method of training our young engineers, but as soon as possible after he has reached his majority the candidate for the commercial side should submit himself to the sandwich system, whereby he is introduced to the commercial phase for short initiatory periods. Having then secured the most promising recruits they must be encouraged to not only study the commercial side but to keep themselves in touch with developments in the technical and practical branches. In a word, they must be commercial plenipotentiaries, but they must also be engineers. Engineers who can worthily demonstrate and readily market those products of the brain and hand which, without commercialism, might go begging.

The scholar, the thinker, the research worker, the inventor, all deserve credit for their contributions to the world's progress, but without the commercial salesman there would be nothing like the enterprise and expansion so necessary for marketing their fruits, and of necessity their efforts would become stultified.

How many classical examples history gives us of the success of invention allied with commercial acumen, and how many inventors and inventions are there to-day neglected and unknown through lack of commercial instinct? Surely it is time to explode the idea that salesmanship lacks dignity. It should be realised that talent can be less worthily and more unprofitably applied than in ensuring a just financial appreciation of its value. Who should be more capable of commercially handling engineering productions than the engineer salesman? But he must be both to be entirely successful as the latter.

PULVERISED COAL AT HAMMERSMITH POWER STATION.—It will be remembered that several months ago a powdered fuel installation was set to work in the Municipal Power Station of the Metropolitan Borough of Hammersmith. This was designed to serve one boiler having a normal evaporation of 48,000 lb. of water per hour. The results were so successful, particularly in enabling extremely low grade fuel to be burnt economically, that on the advice of the chief engineer and manager, Mr. G. G. Bell, the Electricity Committee have decided to put down additional plant to serve three boilers having a normal aggregate evaporation of 128,000 lb. of water per hour. The extensions are being carried out by the Powdered Fuel Plant Company, Limited, of 47, Victoria Street, Westminster, S.W. 1, who also furnished the original installation.

CORROSION OF CHROMIUM STEELS.—Experiments on the Resistance and Corrosion of various Types of Chromium Steels, made by H. S. Rawdon and I. Krynitsky, of the United States Bureau of Standards, are described in *Chemical and Metallurgical Engineering* of July 22, last. Two kinds of tests were made, an acid test and a weather test. For the former the specimen was put into diluted hydrochloric acid, which is highly corrosive to steels and does not give complex decomposition products as nitric acid would do; an excess of acid was always applied. For the weather test, the specimen was suspended, by silk threads, in distilled water which just covered the surface of the steel; the water trough was placed near an open window. All the specimens were small rectangular prisms, ground and sometimes polished on the surface. The results of the two tests did not run parallel, and the corrosion could not be directly connected with the composition of the steel. In the acid test the cast alloys and also the hardened alloys proved more resistant than the forged and annealed alloys, and the highest carbon steels showed the greatest corrosion; pure iron and steel of low chromium contents resisted corrosion better than high chromium steels. To resist the attack by water and air, the steel should contain much chromium, but even a low chromium steel corroded less than a simple carbon steel and pure iron; the rusting of chromium steel was always merely a local pitting; a surface film or rust-crust was never observed. It should be noted, as a point of interest, that the high chromium steels, which stood the weather test best, were also relatively rich in silicon.

DOUBLE-REDUCTION GEARS FOR TURBINES.

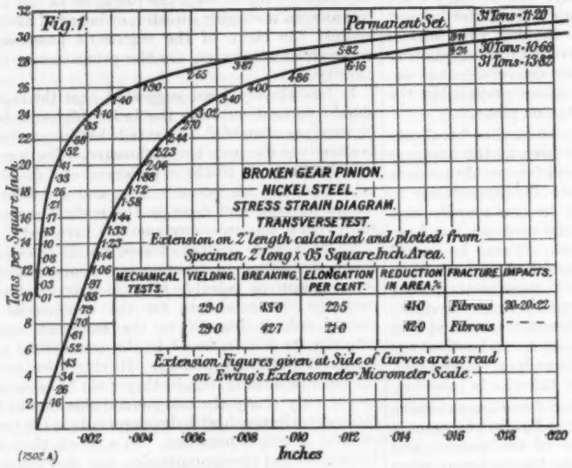


Fig. 1.
Permanent Set.
31 Tons - 11·20
30 Tons - 10·66
31 Tons - 13·82
BROKEN GEAR PINION.
NICKEL STEEL.
STRESS STRAIN DIAGRAM.
TRANSVERSE TEST.
Extension on 2" length calculated and plotted from Specimen 2" long x ·05 Square Inch Area.
MECHANICAL TESTS. | YIELDING. | BREAKING. | ELONGATION PER CENT. | REDUCTION IN AREA % | FRACTURE | IMPACTS.
29·0 | 43·0 | 22·5 | 41·0 | Fibrous | 20-20-22
29·0 | 42·7 | 21·0 | 42·0 | Fibrous | - - -
Extension Figures given at Side of Curves are as read on Ewing's Extensometer Micrometer Scale.
Tons per Square Inch.
Inches
(7502 A)

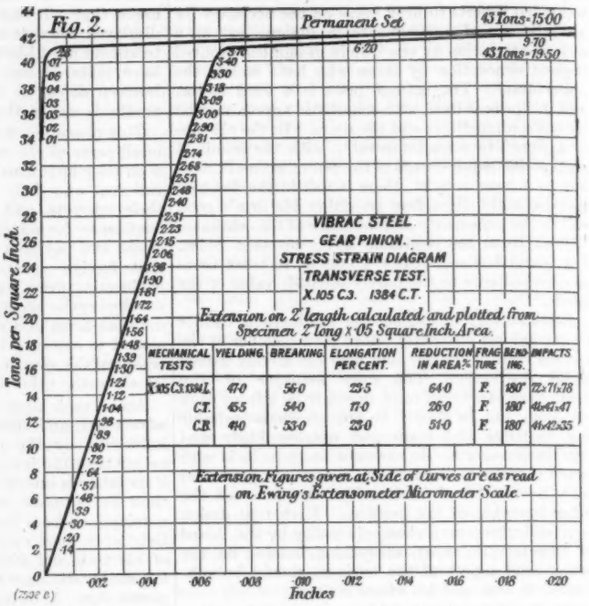


Fig. 2.
Permanent Set
43 Tons - 15·00
43 Tons - 19·50
VIBRAC STEEL.
GEAR PINION.
STRESS STRAIN DIAGRAM.
TRANSVERSE TEST.
X.105 C.3. 1384 C.T.
Extension on 2" length calculated and plotted from Specimen 2" long x ·05 Square Inch Area.
MECHANICAL TESTS | YIELDING | BREAKING | ELONGATION PER CENT. | REDUCTION IN AREA % | FRACTURE | BENDING | IMPACTS
X.105 C.3. 1384 L | 47·0 | 56·0 | 23·5 | 64·0 | F. | 180° | 72, 71, 78
C.T. | 45·5 | 54·0 | 17·0 | 26·0 | F. | 180° | 41, 47, 47
C.B. | 41·0 | 53·0 | 23·0 | 51·0 | F. | 180° | 41, 42, 35
Extension Figures given at Side of Curves are as read on Ewing's Extensometer Micrometer Scale.
Tons per Square Inch.
Inches
(7502 B)

"DOUBLE-REDUCTION GEARS FOR TURBINES."

TO THE EDITOR OF ENGINEERING.

SIR,—The leading article in your issue of August 11, dealing with the recent failures of the double-reduction gear pinions is of great importance to both engineers and steel manufacturers. The contention that the designers or makers are entirely at fault because many "no trouble" sets of double-reduction gearings are still at work, does not appear to be altogether just. On serious consideration from all points of view, it would appear that the possibilities of the steel being variable are greater than machinery errors.

Although it may be claimed that the nickel steel employed in their manufacture may be good, there is always the possibility of it containing non-metallic enclosures which may cause the ghost mark appearance, and any such marks at the roots of teeth are, unquestionably, weakness. Again, in the process of treatment, the best structural condition may not have been produced. These defects are rarely indicated by the ordinary commercial method of testing.

It is a well-known fact that different forgings of steel possessed of the same excellent mechanical properties may give Izod impact figures of from 6 ft.-lb. to 60 ft.-lb. If, as we believe, the impact test is an index of the brittleness of the material, engineers should insist on an impact test in addition to the usual mechanical test. Further, where machine parts are stressed in a transverse or circumferential direction, the impact test should be taken in the same relative direction.

An inherent weakness in nickel steel in the treated condition, which, on the commercial testing machine, is not detectable, is its liability to have a relatively low "true" elastic limit. Tested by the Ewing extensometer, the "true" elastic limit is proved in certain cases to be about 10 tons in place of 25 tons to 30 tons as usually reported on a steel giving a minimum tensile test of about 40 tons.

The curve (Fig. 1) giving the results of tests a portion of a nickel steel pinion which failed in service, indicates this very clearly. The companion curve (Fig. 2) gives comparable results from a pinion made from Messrs. Sir W. G. Armstrong, Whitworth's "Vibrac" steel, from which steel a large number of double-reduction gear pinions have already been supplied. It will be noted that this material in addition to giving a high true elastic limit and high maximum stress also gives a relatively high impact figure, indicating its freedom from brittleness.

Yours truly,
WM. C. ROWDEN.

Ashton-road, Openshaw, Manchester,
August 23, 1922.

"VANE WHEEL PROPULSION OF SHIPS."

TO THE EDITOR OF ENGINEERING.

SIR,—Reverting, with your permission, to your footnote in issue of July 7, I submit that the arrangement devised by Mr. Barcroft is not essentially differentiated from that carried out by Messrs. Denny by the fact that in one case the immersion is more than half the disc and in the other case less. In both cases there is an essential difference from a totally immersed propeller in that (1) the effective disc area is less than the total, (2) there is involved a considerable bending stress on the shaft, (3) slow speed of revolution is desirable, if not indeed essential, on account of the tendency to draw down air. On reference to Mr. Barcroft's paper it will be found that, with his necessarily limited diameter of propellers owing to the narrow beam of the canal boats, he found that better efficiency was secured by a deeper immersion than half the disc, and that he had tried various immersions before arriving at the most favourable depth. Not only so, but when the boats were light it was usual to have the shafts above the water line. I have been unable to find the old drawings of partially immersed or screw paddle wheel propellers, but in the discussion on Mr. Barcroft's paper the late Mr. James Platt stated that, many years earlier, David Napier built a boat 110 ft. by 17 ft. which had two screw wheels 5½ ft. to 6 ft. diameter placed so as to be about half above the water.

In the sixth edition of "Marine Propellers," by S. W. Barnaby, page 123, it is stated that, in 1862, Sir John Thornycroft proposed to place twin screws in a vessel of light draught, with their shafts above the water line, so that the lower blades only propelled. Some few weeks ago I had sent to me by a friend illustrations of skimming boats, called by the builder (Hickman) "Sea Sleds," which have been built in America, driven by semi-submerged screws, which have attained a high speed, and these are also mentioned by Mr. Barnaby. He further states that recently a coastal motor-boat was fitted for experiment by Messrs. Thornycroft, with a pair of propellers which had only ·35 total disc area immersed at full speed, and the speed, although not bad, was considerably less than that given by the single screw as usually placed in a boat of the same size and power.

Yours faithfully,
Gloucester, August 30, 1922. W. SISSON.

"THE COMMERCIAL VALUE OF KNOWLEDGE."

TO THE EDITOR OF ENGINEERING.

SIR,—Your article on the "Commercial Value of Knowledge" published in to-day's issue of ENGINEERING, is very interesting, and shews very clearly to the embryo engineer the extent to which his training is valued by engineering firms of the present day. The article appears to be written, however, without a clear insight into the mind of the third year post-war student, and I cannot let some of your statements pass unchallenged.

May I point out at once that among my colleagues of University College, London, not one is suffering from disillusionment with regard to employment at the present time. Most of us on taking up the three years engineering course, found at the time, that it was absolutely impossible to secure a post without being qualified. At the time of our demobilisation trade was at a standstill—the engineering firms dismissing large numbers of men—and preferring to work in some way or other than to swell the ranks of the unemployed, we took the only opening offered to us, viz., the Government offer of higher education for ex-service men. The men with some previous technical training entered engineering colleges.

Endeavour to realise the state of affairs. Four years or more of nerve-shattering war, and then to settle down to three years "grind" at college. Not one of us fully comprehended what close application to study really meant, but we were not left long in doubt. The Board of Education demanded terminal reports as to our conduct and progress, the shirkers were quickly discovered and requested to leave college. The others, more conscientious perhaps, bent themselves to their task and determined to shew something in return for the expenditure of public funds upon their training.

It will be enlightening and instructive at this point to consider the curriculum at a London engineering college. The first year is spent in learning the elementals of engineering drawing, graphics, comprising structures, &c., and the usual subjects of mathematics, applied mechanics, chemistry, physics and French. At the end of the first year, the average student who has completed thirty drawings (approximately) in pencil and ink, sits for his intermediate engineering examination. The successful candidate then enters upon his second year, in which he specialises in civil, mechanical or electric engineering. The third year is a development of the second year, with one or two extra subjects. During the second and third year of the course great attention is paid to the practical side of the training, and the student spends most of his time in the mechanical laboratory and drawing office. The average student in these two years completes 300 foolscap pages of laboratory reports on testing of machinery, strength of materials, heat engines and hydraulics, and in all 40 drawings (approximately) in pencil and ink in design of steam and oil engines, structures, &c. The lectures in the theory of these subjects take place during the morning, so that the whole of the drawing and experimental laboratory work is done during the afternoon. Reports and revision, &c., take up most of the evening at home. I should have added that in addition to the above subjects the civil engineer takes surveying and municipal engineering, and the electrical engineer—electrical technology, the courses in each case being essentially practical.

You will see, therefore, that the post-war student is not allowed to slack, and if he manages to pass his diploma and degree examinations, it is only by dint of perseverance and close application to study. Again, the degree and diploma requirements are such as to eliminate all but the practical man. One *must* pass in the course work apart from the usual examination in the theory.

There are not many ex-service students left at college now. The majority of us have finished our training this year, and are prepared to earn our living not in a "designing" capacity as you suggest, but in a very humble way. We thoroughly realise that we lack commercial experience, but we are scarcely "youths," and it is a misnomer to apply the term to men with four or five years of war service behind them. The youngest of us must be nearly twenty-five years of age. We trust that we lack neither courtesy nor energy, and yet after weeks of patient application we are unable to secure posts in the humblest capacities.

I suggest that a man with an "academic distinction" is at least capable of earning 3*l.* per week, say, as a junior draughtsman—(this being in my opinion the minimum living wage for a man of intellect). Rest assured he would prove satisfactory and earn every penny of his wage. At the same time he would be gaining the much needed commercial experience, and would remember with gratitude the man who set his feet upon the first step of the ladder of his profession.

We are eager and willing to start at the lowest rung but who is going to give us the start?

Yours faithfully,
August 25, 1922. "GRADUATE."

"STATES AND ENTITIES; WHAT IS ENERGY?"

TO THE EDITOR OF ENGINEERING.

SIR,—Your correspondent who has read ENGINEERING for 52 years has certainly done so to his own advantage and to that of others who have had the benefit of what has been published in your journal on the same question during the past 10 years; and I trust that the expression of such views may lead to the more general adoption of sound teaching in place of the jargon of the text-books which is too often relied on by our professors.

The example of ice, water and steam being different forms and conditions of H_2O is a happy one, and it will help many of us to realise more clearly than heretofore the difference between states and entities.

Yours, &c.,
Bristol, August 30, 1922. "B.Sc. (Lond.)."

NOTES ON NEW BOOKS.

THE ordinary problems of electric motors have been solved so long ago—long, at any rate, in our age of rapid electric development—that we do not frequently meet with new books on the subject now-a-days. Modern treatises on this subject, unless devoted to special features, are indeed not likely to contain much novel information. The author of the modern treatise has—or should have—the advantage of mature experience, however, and should find it more easy than his predecessors to separate the essential and approved from the unimportant and impractical. This, we think, has been done by Karl Meller in his "*Elektromotoren in ihrer Wirkungsweise und Anwendung*" (Berlin: Julius Springer; price 6*s.*). The volume of 120 pages octavo is compiled with the object of helping the technical man and engineer in making a choice of electric motors for the factory and special machines, and in understanding their working and installation, and it seems well suited for that purpose. The language and mathematics are clear and simple, and there is a certain novelty about the diagrams. References may have been omitted because a literature list would have been very long; an index should have been added, however, though it may not be greatly missed.

We confess to feeling some sympathy for Mr. Philip Gates, of a work by whom we gave an appreciative notice a short time since, "*Jigs, Tools and Fixtures.*" It seems a pity that he should have been asked to treat of the very wide subject of capstan and automatic lathes in a slim foolscap octavo volume of 82 pages. (Sir Isaac Pitman and Sons, Limited) and 35 illustrations, some of which are full-page photographs; 44 pages are occupied with the capstan lathe. The author has condensed as much as possible in his treatment of chucking, and tools, but drawings of capstans and the operating mechanisms of the lathes cannot be included. Into 37 pages are condensed four chapters devoted to automatic lathes, the Brown and Sharpe, the Cleveland, the Gridley and the Potter and Johnson. Chapter VI, on the Lubrication of Cutting Tools, occupies 5 pages, followed by a bibliography and index. The price is only half a crown, but the treatment is too abbreviated to possess more than a superficial value. This must not be laid to the charge of the capable writer.

One of the disadvantages under which preachers labour is that the kind of men who would profit most by their admonitions are not to be found amongst their congregations. The writers of useful books often suffer from similar conditions. A little work, entitled "*A Series of Notes on the Care, Working and Maintenance of Dynamos and Electric Motors,*" published by the National Boiler and General Insurance Company, Limited, of Manchester, at the price of 1*s.* 6*d.*, serves to illustrate this truth. The book in question, the contents of which are sufficiently indicated by the title, is addressed to the owner and operator of electric machinery. If designers could be got to read it and to apply themselves to the task of eliminating the possibility of such troubles as the operator is told how to avoid, much good would be done. Among other things, the motor attendant is advised to drill holes through the end covers of totally-enclosed machines, so that he may be able to verify the clearance between armature and fields, the holes being filled with removable screwed plugs. This is not really a job for a motor attendant at all. The holes would have been there already if the designer had had a practical knowledge of the features which really connote good design. More should not be expected of a machine attendant than is absolutely necessary, and it ought to be the aim of the designer to render trouble impossible. He will fit himself best for this task by pondering over the defects which are revealed by working, and of which only too often he never hears.

GEODETIC TRIANGULATION OF FRANCE.—The Paris journal *Le Temps* gives particulars of geodetical questions which have been dealt with at the Congress for the Advancement of Sciences recently held at Montpellier. It is stated that the French Ministers of War and of the Liberated Regions are considering dealing afresh with French triangulation. The existing triangulation of France is that on which the present official map of the country, on the scale of 1 : 80,000, commenced in 1790, has been drawn. Work in the same field was undertaken but discontinued, at different times. The late war has made the matter one of urgency. Many of the geodetical points in the liberated regions were represented by church steeples. Over 1,000 of these have been entirely destroyed, in fact, a careful census recently made of 4,500 such points shows that 1,200 no longer exist, following upon the war. On the other hand, the war has demonstrated the necessity for military operations of maps on a comparatively large scale, and the plotting of the survey on the scale of 1 : 20,000, 10,000 or even 5,000 would be found of the greatest value by all public services and private owners of land and contractors.

CAST IRON AND ITS CHEMICAL COMPOSITION.*

By O. SMALLEY.

CUPOLA-melted cast-iron is a material of unknown thermal stability, a mechanical mixture of elements and compounds which only by careful manipulation can be arranged, within certain limits, to give physical properties that render it a reliable material of construction.

Because of its economic value, the metallurgist has long endeavoured to bring it into line with steel, brass and such alloys whose physical properties are under perfect control. Recent reports give the impression that our present lack of knowledge of the metallurgy of cast-iron is a result of the scientist having concentrated

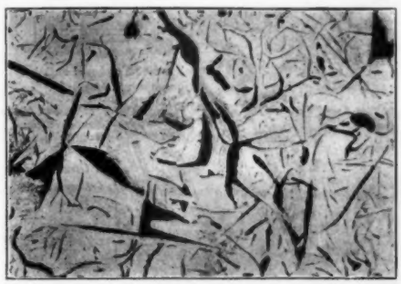


PHOTO. A.

PHOTO. B.

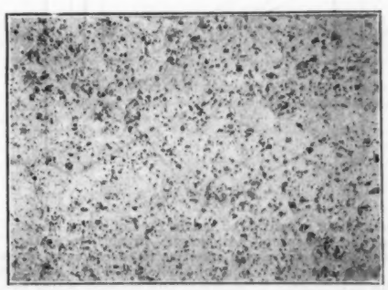


PHOTO. C.

his attention elsewhere. To a certain extent this is true because a knowledge of the constitution of a simple series of elements is essential to an understanding of a more complex series. At the same time, although cast-iron belongs to the latter, it has been closely studied alongside with the simpler combination to which it is allied, viz., steel; and although we possess a more comprehensive understanding of the physico-chemical properties of the iron-carbon, and the iron-carbon-manganese combinations, it is only because they give rise to a series of true alloys whilst the combination of elements known as "cast-iron" does not.

Moldenke speaks of cast-iron as a "Conglomeration of elements which is little understood." This aptly sums up the position with regard to our present knowledge of the constitution of cast-iron. In all there are 18 to 20 different elements in cupola-melted iron, which, giving rise to the presence of compounds of widely different chemical and physical properties, possesses certain definite limitations.

A recognition of these limitations and a knowledge of the fundamental principles controlling the production of any particular combination of physical properties is the urgent need of to-day, not development as a competitor with steel.

* Paper read before the British Foundrymen's Association at Birmingham.

Chemical Composition.—The elements present in cast-iron, of which we have a working knowledge, are C, Si, Mn, P and S.

The maximum and minimum amounts of these elements are as follows:—

	Per Cent.
C	2·8 to 3·9
Si	0·8 to 5·0
Mn	0·3 to 1·3
P	0·10 to 1·80
S	0·05 to 0·20

If, however, a census were taken of the foundries that controlled the physical properties of their castings by chemical composition, they would, I fear, be found to be in the minority. This, together with the fact that iron castings made hundreds of years ago—before the advent of the chemist into the foundry—have been found to equal the best castings that are made to-day, indisputably establishes the limitations of ordinary chemical analysis and proves that composition in itself is no criterion of the value of a casting in service.

The chemical composition of cast-iron is somewhat analogous to that of a moulding sand, it indicates principal elements present, but it does not give any idea of the chemical or physical constitution of the compounds formed, and their relation to one another, which factors control its utility. In other words chemical composition is of little value without a knowledge of the metallurgy of cast-iron. Unfortunately the metallurgy of cast-iron as previously stated, is so complex that as yet it is far from being an exact science; in fact so many problems require immediate elucidation to-day that a close co-operation of the metallurgist and foundrymen is essential to the successful production of commercial iron castings.

Semi-Steel.—Recently a large and reputable manufacturer of refined cast-iron submitted for inspection various selling samples of his products. Amongst these was one which had been forged down to a wedge shape, so prepared to demonstrate the quality of this iron for the manufacture of high grade cylinder castings. On analysing, the following composition was obtained:—

	Per Cent.
C.c.	0·64
Gr.c.	1·21
Si	1·32
Mn	1·32
P	0·082
S	0·060

This proved it to be nearer a steel than cast-iron and to have been made by an oxidising process from steel scrap, pig-iron and ferro-silicon additions.

What advantage is to be gained by the use of this iron in the cupola? Is it superior to refined iron made in the cupola to the following composition:—

	Per Cent.
T.C.	2·9
Si	1·32
Mn	1·32
P	0·10
S	0·060

This incidently can be prepared at one-third the cost. It may be argued that a refined cast-iron cannot be prepared in the cupola from cast-iron and steel scrap, in that it will contain a high total carbon, possibly oxygen or oxide of iron—a much discussed bogey of to-day—and be high in sulphur. Yet surely this is the material which the engineer means when he specifies semi-steel. It can be nothing more or less than cast-iron melted with steel; it cannot be recognised from ordinary cast-iron by chemical analysis.

Semi-steel is sometimes defined as low-carbon cast-iron. This, however, is incorrect, there being little difference in the total carbon content of cast-iron melted without steel and that melted with, say, up to 25 per cent. Nor is it safe to assert that steel is either detrimental or beneficial because of the oxygen introduced, both assertions having frequently appeared in recent publications on the subject. If steel is melted with cast-iron in a correctly-designed cupola, using a good hard coke, the correct volume of air and is suitably fluxed, there is nothing to choose between semi-steel and cast-iron so far as fluidity and the production of clean castings are concerned. The addition of steel, however, is beneficial in that it gives a closer-grained, tougher and better-wearing iron and improves the solidity of the casting as a whole. This is a conclusion proved by many years of practical experience. This improvement is directly attributable to the quantity and form of the graphitic carbon present. It has nothing to do with oxygen, nitrogen or any of the so-called inherent properties of the irons used in the first place. In fact, Cleveland, hematite and scrap mixtures yield results equal to specially-selected cold blast or open hearth refined irons, if the form of the graphite is controlled in the first instance. This may be demonstrated in various ways, *e.g.*, if molten mild steel plus the necessary additions of silicon and phosphorus is run through a small cupola charged with incandescent coke, an abnormally tough iron will be obtained although of normal chemical composition. If a microscopical examination be made of this synthetic iron, and also of ordinary cast-iron it will be found that in the former the graphite is finely disseminated through the mass, whilst in the latter it exists as coarse flakes.

The explanation of this difference is that in ordinary pig-iron the total C content ranges between 3 per cent. to 3·9 per cent. and the graphitic carbon not only possesses different degrees of refractoriness, but exists in various forms determined by chemical composition and method of manufacture. Photographs A, B, C, annexed, illustrate the form of graphite commonly met with in cast-iron. Photo. A represents a 3-in. square block of

hematite cast in dry sand. B the same iron cast in the form of 1-in. bars and C when die-cast.

Speaking generally, the coarser the graphite flakes the more refractory does it become. In the cupola it is doubtful if a higher temperature than 1,480 deg. C. is ever reached. The maximum amount of carbon a 2 per cent. Si iron can hold in solution when just molten is round about 3·7 per cent. Assuming that the ordinary laws of solution hold for cast-iron, then at 1,480 deg. C. such an iron will dissolve about 3·95 per cent. C. Cupola melting, however, is extremely rapid, and the molten iron rarely reaches this temperature, in consequence high carbon grey irons melted in the ordinary way always contain some free graphite. This fact does not appear to be fully appreciated, although it may be proved by anyone interested by pouring the molten iron in cold water and examining chemically or microscopically.

The effect, then, of coarsely disposed graphite in the pig melted is to adumbrate in the molten metal the original structure and reproduce it in the finished casting to an extent determined by the rate of cooling during solidification. If, however, such a graphitic iron is rapidly solidified, say, *e.g.*, by casting in chill moulds, the graphite flakes are broken up into a fine granular form, photograph C, page 277. Remelting the iron yields tough, close-grained castings. This has been demonstrated by many large-scale practical experiments, melting in 8-ton and 16-ton cupolas, closely observing the quality of the finished castings and the physical test results in conjunction with the microstructure. That 10 per cent. to 15 per cent. mild steel should have a further grain refining influence if melted in conjunction with this chill cast run-down iron, can readily be understood. In fact, this mixture not only eliminates such common defects as open grain and sponginess, but renders possible the reproduction of certain physical properties to a remarkable degree of accuracy. The following test results obtained from daily test bar records, represent the maximum and minimum obtained from many thousands of tons of this iron made over long periods of time :—

C.c.	Gr.c.	T.c.	Si.	Mn.	S.	P.	Tensile Tons per Sq. In.	Transverse (12 in. by 2 in. by 1 in.) Tons.
0·74	2·41	3·15	1·5	0·65	0·11	0·50	16–19	5·0 to 6·6
0·67	2·43	3·20	1·8	0·65	0·100	0·75	14–17	4·5 to 5·5

Oxygen in Cast-Iron.—Considerable discussion has taken place recently as to whether oxygen can be found in cast-iron, and its effect on the mechanical properties. That oxide of iron may exist in badly-melted iron is now generally accepted, and that under such conditions the addition of steel will not materially assist. Whether oxygen exists in cast-iron as a gas has yet to be proved ; in fact, we do not pretend to understand the chemical equilibrium between iron, carbon and oxygen. Yet, some investigators go so far as to state that oxygen is soluble in cast-iron and that semi-steel owes its superior physical properties to the oxygen introduced by the addition of steel. J. Johnson, junior, who first published this statement, offers no premises for his conclusion, and from the outline given of his experiments one is quite as justified in asserting that the improved physical properties are an effect of hydrogen or nitrogen, gases which we know do exist in cast-iron, or to the form of the carbon or to a direct temperature effect.

It is equally certain that dirty castings and blowholes cannot be directly attributed to oxygen as cupola-melted cast-iron, no matter what care be taken in melting, will give dirty and blown castings if cast at a low temperature ; whilst the cheapest grade of iron, whether melted with or without steel, yields clean castings if the metal is correctly melted and is cast at a good temperature.

Chemical Composition.—To investigate the question of the effect of oxygen and its oxides on the physical properties and production of clean castings, a continuous series of experiments has been carried out during the past twelve months on a large and extensive practical scale by treating various grades of iron with the most active deoxidants. Amongst those tried were cerium, uranium, calcium, vanadium, aluminium, magnesium, manganese and zirconium, all of which are well-known for their ready affinity for oxygen.

Cerium.—In a recently-published American investigation the following conclusions were drawn on the effect of cerium : "Deoxidising by means of cerium gives the purified molten metal a better chance to set under natural conditions, being relieved from a too rapid freezing action with consequent formation of undue amounts of combined carbon. The metal, therefore, is easier to machine, is freed from gas and pin holes, has a less internal shrinkage and increases the transverse strength 33 per cent. with a proportional increase in the deflection."

Attempts have been made to confirm these remarkable statements, introducing 0·01 per cent., 0·05 per cent., and 0·10 per cent. of cerium by means of a 70 per cent. Ce ferro-cerium alloy in stick form. In each instance the cerium alloy was copper-plated, fastened to the end of a steel rod and plunged in the molten metal to the bottom of the ladle. This caused a violent ebullition and a slight increase of temperature.

Though many experiments were carried out with both cupola and crucible-melted cast-iron, no beneficial effects could be traced to cerium when introduced in quantities up to 0·05 per cent.; with 0·10 per cent. a slight strengthening effect was found in two instances, but there was no increase in fluidity or decrease in shrinkage. In fact, there was every indication that the increased strength from the introduction of 0·10 per cent. Ce was a temperature rather than a cleansing effect.

Uranium.—This was introduced in the form of powdered ferro-uranium, containing 41 per cent. uranium enclosed in a small sealed tin box, fastened to the bottom of the ladle, the molten metal being tapped direct from the cupola.

Fluidity, shrinkage, tensile and transverse tests show uranium in quantities of under 0·20 per cent. to be without effect on the quality of ordinary cast-iron.

Calcium.—These experiments were conducted on the same lines as adopted in the cerium experiments, using pure calcium in one series and ferro-calcium in another.

No real benefit was found in any instance, and no trace of calcium could be detected in the finished castings.

Vanadium.—Moldenke, in summarising his experiments concludes that "to increase the breaking strength of grey cast-iron a further investigation on the effect of vanadium is warranted on the part of every foundryman who has special problems in strength to master." Hatfield after exhaustive investigation does not attribute the slight beneficial effect of vanadium which he found in his experiments to be due to this element acting as a scavenger, but rather to its influence in preserving the carbon in the combined state.

In my own experiments a 35 per cent. vanadium (ferro-vanadium) alloy was used, introduced in quantities up to 0·10 per cent. in the manner adopted with uranium.

The test results obtained do not confirm Moldenke's assertion that small quantities of vanadium are beneficial to the production of a high tenacity iron ; whilst the hardening effect observed by Hatfield was not found ; which suggests that Hatfield's results are more than probably accounted for by either a variation in the casting temperature or the initial temperature of the mould, factors which he does not appear to have taken into account.

Aluminium and Magnesium.—Extensive experiments have been conducted with these metals, introduced separately, alloyed with each other, and also alloyed with iron and copper. The only direct and reproducible effect of aluminium found was to soften ; whilst magnesium hardens. No improvement in the fluidity and physical tests could be detected by the introduction of either metals into normally-melted cupola iron. The introduction of magnesium into cast-iron is accompanied by a violent reaction, and great precautions are necessary.

Zirconium.—Moldenke (American Foundrymen's Association, October 4 to 8, 1920) failed to find any beneficial effects from the use of zirconium if the iron is melted with the right degree of heat. If, however, large amounts of steel scrap are used he states "it might be beneficial."

In my own experiments, I could detect no improvement from the introduction of zirconium in quantities of up to 0·20 per cent., whether steel was or was not melted with the iron, or whether a hot or a cold blast iron was used.

The collected tabulated physical test figures accompanying these experiments are excluded from the paper on account of their bulkiness, but the comments made fully, though briefly, summarise the results obtained and convey all that is necessary so far as "deoxidation of cast-iron" is concerned. Moldenke, in summing up the results of his experiments on the effect of zirconium states "if cast-iron is correctly melted in the first place, nothing is to be gained by the use of zirconium, but if melted with steel it might be beneficial. The first portion of this comment applies to practically all deoxidants and which is more important, to incorrectly-melted iron, because no amount of doctoring will correct such iron and render it fit for use.

Casting Temperatures.—The initial melting and casting temperatures are two essential factors governing the successful production of clean, solid castings. If the metal is cold on leaving the cupola, bad castings are inevitable, no matter what precautions are taken in other directions. On the other hand, if it contains the necessary degree of superheat, and is cast at the right temperature little or no trouble will be encountered so far as blowholes, scum and physical test results are concerned, assuming of course the correct mixture has been used in the first place.

During recent years many attempts have been made to measure and so control the degree of superheat in cupola-melted iron, but with little or no success, as the temperature figures quoted by recent investigators show, these ranging from 1,300 deg. to 1,592 deg. C. To measure accurately the temperature of molten cast-iron in the foundry an actual immersion of a thermocouple is the only satisfactory method. To be of practical utility the couple must be robust and reasonably foolproof. Of the numerous couples tried only two have been found worthy of consideration, the one, composed of alumel (Ni 95 and Mn 2, Al 2) chromel wires (Ni 89, Cr 8, Mn 1·5, Fe 0·5), the other platinum and platinum alloyed with 10 per cent. rhodium. The former has an advantage in that the first cost is low, whilst with the latter it is very high. Unfortunately the life of the base metal couple at temperatures above 1,200 deg. C. is short no matter what combination of protecting sheathes are used, so that its use had to be subsequently abandoned.

Fig. 1 illustrates diagrammatically the rod finally designed with the rare metal couple. Two of these rods were made fifteen months ago and have been in daily use at temperatures ranging from 1,300 deg. to 1,420 deg. C with little or no change in the E.M.F. constants or depreciation in the value of the wire. The total upkeep has consisted of six new outer protecting sheathes. Warming the end of the rod over a coke fire or gas burner before immersing in the molten metal, although not essential, reduces the lag to under 5 minutes, and prolongs the life of the refractory protecting sheath. On withdrawing from the ladle of molten metal adhering slag should be carefully removed and rod stored in a warm place. A mixture consisting of 5 parts China clay, 1 part alundum cement and 4 parts graphite, made up to a cream consistency with a 5 per cent. aqueous solution of 70 deg. Twaddle sodium silicate, applied to the end of the rod after use, materially prolongs the life of the refractory sheath. By the aid of this pyrometer it has been possible

Fig. 1.

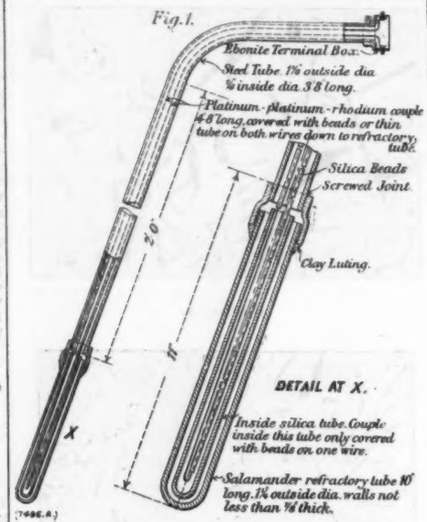
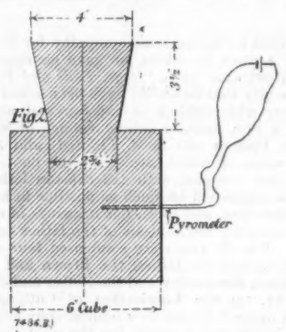

Ebonite Terminal Box.
Steel Tube. 1" outside dia. ⅝ inside dia. 3'8 long.
Platinum-platinum-rhodium couple 4'8 long, covered with beads or thin tube on both wires down to refractory tube.
Silica Beads
Screwed Joint
Clay Luting.
1'0"
1'1"
DETAIL AT X.
X
Inside silica tube. Couple inside this tube only covered with beads on one wire.
Salamander refractory tube 10" long. 1" outside dia. walls not less than ¼" thick.
(7496.A.)

Fig. 2.



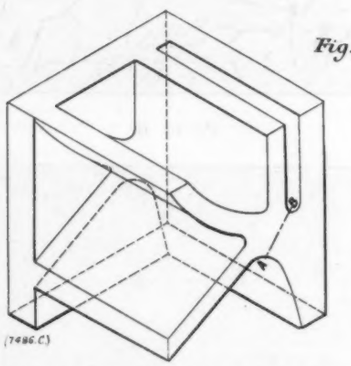
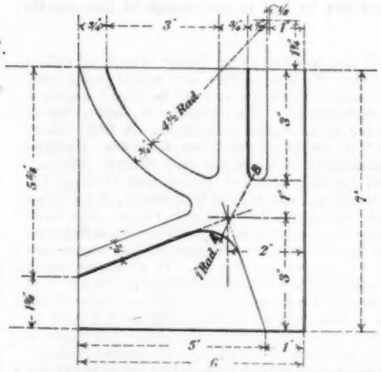


Fig. 3.



to investigate many of the peculiarities of the cupola, standardise melting operations, and control the casting temperature to a high degree of accuracy.

Casting Temperature and Composition.—The effect of casting temperature was first demonstrated with crucible melted cast-iron by Longmuir, in 1903. Since this investigation the importance of correct casting temperature has been recognised, although I do not know of any efforts to correlate casting temperature with composition.

The necessity of this is seen from Table I, on the next page, giving the temperatures of incipient and final solidification of the irons commonly made in the cupola. These temperatures were obtained by means of a platinum and platinum-rhodium thermocouple placed just off the centre of a 6-in. cube made in dry sand, Fig. 2. Whilst it is not possible to consider in this paper all the factors governing the selection of the range of temperature within which any particular casting must be poured to obtain the best results, it is clearly evident that each iron must be considered on its own merits if any measure of success is to be obtained.

For general practice 10 per cent. of superheat may be taken as a working figure for castings made to specified physical test which must machine with clean faces. This means for hard irons containing a normal total carbon content, 1 per cent. Si and low in P, the casting temperature should be round about 1,370 deg. C. In the presence of 1·5 per cent. P incipient solidification falls 22 deg. C. so that the casting temperature is reduced to 1,343 deg. C. Iron No. 3, suitable for the manufacture of high grade cylinders and cylinder liners, and for

PHOTO. D. PHOTO. E.

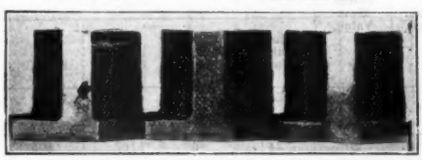


PHOTO. F. PHOTO. G. PHOTO. H.

PHOTO. I. PHOTO. J. PHOTO. K.

castings to withstand superheated steam, the casting temperature is 1,355 deg. C. For ordinary cylinder irons containing 1·5 per cent. Si and 0·50 per cent. P, 1,331 deg. C. A 2 per cent. Si iron, low in P, commences to solidify at 1,212 deg. C. (Coe, Journal Iron and Steel Institute, 1913) which brings the casting temperature to 1,333 deg. C. In the presence of 0·8 per cent. to 1 per cent. P, incipient solidification falls 47 deg. C., so that the casting temperature is correspondingly lowered; whilst for a soft iron high in silicon and phosphorous it is 1,276 deg. C.

These figures, whilst amply demonstrating the correlation of composition and casting temperature, are by no means arbitrary. They are, in fact, only of practical value if considered alongside with the physical attributes of the irons melted, the range of temperature through which they solidify, mass effect and requirements of the finished casting.

Solidity of Cast-iron.—Grey cast-iron does not possess true solidity as this is understood to exist in pure alloys. The degree of solidity is a direct function of the quantity and form of the graphite present, everything else being equal. The quantity and form of the graphite being determined by chemical composition, casting temperature and rate of cooling during solidification, solidity is a property under direct control. It is, of course, admitted that peculiarities are met with in the cupola-melted cast-iron which are not easily explained; these, however, are the exception rather than the rule.

To exemplify the effect of composition on solidity in a practical way, a series of castings was made of the form shown by Fig. 3. This casting represents one of the most complicated sections with which the foundryman has to contend; one that is a constant source of trouble in all classes of cylinder castings, through porosity. The castings were purposely made with the heavy section at the bottom and without risers.

The method of melting, casting temperature, head of metal, initial temperature of mould, &c., were carefully controlled throughout the experiments in order to eliminate as far as possible all variables except chemical composition. Each casting was sectioned through A B, the position of drawing according to the isothermal lines of casting.

Photographs D and E, annexed, depict the drawing which has occurred with an ordinary soft grey iron of the following chemical composition :—

T.c.	Si.	Mn.	P.	S.
3·27	2·20	0·72	0·91	0·096

an iron commonly used on account of its apparent non-shrinking qualities. Each was cast from the same ladle of metal, D being poured hot at a temperature of 1,370 deg. C. and E poured cold, 1,280 deg. C. Photograph G represents a casting made from the same alloy to which 0·25 per cent. Mo has been added, casting temperature 1,360 deg. C. This experiment suggests that molybdenum minimises the drawing defect common to ordinary soft grey iron.

Photograph H shows the result obtained with a high Si, high P iron of the following chemical compositions :—

C.c.	0·50
Gr.c.	2·84
T.c.	3·34
Si	2·50
Mn	0·56
P	1·83
S	0·046

and, although an improvement on G, it is by no means solid. These experiments were confirmed and various grades of other soft irons tried, but with no better results.

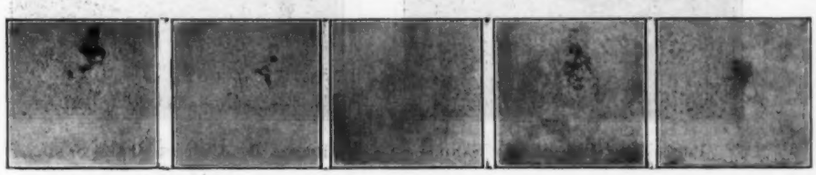
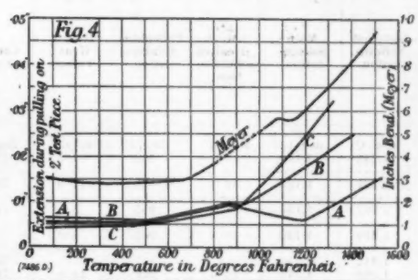


PHOTO. L. PHOTO. M. PHOTO. N. PHOTO. O. PHOTO. P.



	C.c.	Gr.c.	T.c.	Si.	Mn.	P.	S.
A	·60	2·66	3·31	1·50	·74	·49	·112
B	·60	2·41	3·08	1·98	·57	·096	·089
C	·15	3·5	3·65	2·92	·49	1·26	·062

Photographs I, J and K portray the results obtained from the harder series of irons. The chemical composition of each is given below :—

—	C.c.	Gr.c.	T.c.	Si.	Mn.	P.	S.	Mo.
1	0·43	2·08	3·41	1·41	0·60	0·90	0·072	—
2	0·63	2·86	3·49	1·25	0·68	0·20	0·089	—
3	0·79	2·72	3·51	1·31	0·68	0·53	0·085	0·25

A material all-round improvement is evident, whilst No. 2, a low Si, low P iron, leaves little to be desired, the casting possessing a uniform solidity throughout.

The results of these experiments are contrary to what one would have expected from the ordinarily accepted theories of the effect of silicon and phosphorous on the volume changes of cast-iron during solidification, but they clearly demonstrate the effect of these two elements on solidity. These experiments are confirmed by the results of the K test bars, which have been made daily in the foundry over a period of years.

Effect of Mass on Solidity.—In the first series of experiments conducted on mass effect, a set of 6-in. cubes was cast in the following irons :—

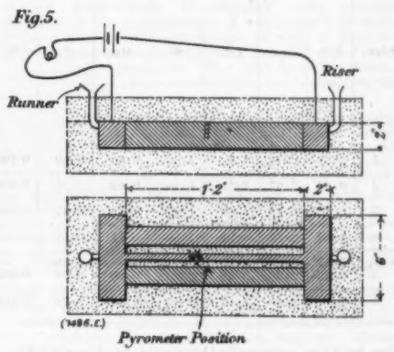
—	C.c.	Gr.c.	T.c.	Si.	Mn.	P.	S.
1	0·55	2·83	3·38	2·3	0·60	0·78	0·063
2	0·24	2·88	3·12	2·49	0·52	1·28	0·050
3	0·66	2·74	3·43	1·20	0·63	0·09	0·063
4A	0·73	2·15	2·88	1·47	0·55	0·50	0·096
5	0·60	2·67	3·27	1·15	0·62	1·54	0·036

Each was poured with 10 per cent. superheat into dry sand moulds, the initial temperature being controlled at 110 deg. F. Photographs L, M, N, O and P, illustrate each cube after sectioning vertically through the middle. In principle these experiments confirm the results obtained from the draw test experiments, and are self-explanatory of the relation between chemical composition and mass so far as solidity is concerned. It will be observed that alloy No. 3 (Photo. N), containing 1·2 per cent. Si 0·07 per cent. P, is equally solid throughout.

According to Turner, ordinary grey iron expands on solidification, the higher the silicon and the phosphorous content, the greater the expansion, and the wider the range of temperature through which it operates. What do Turner's expansion figures mean? Do they infer that grey cast-iron does not shrink during solidification? If so, why did the high silicon irons in the draw test bars shrink at the thicker portions, which shrink-hole or spongy place is nothing more nor less than a pipe due to there being no residual liquid left to fill the interstices of the primary Skelatal arms of the crystals; a defect all too common in iron castings. Again, why did the low Si and low P iron pipe the least in the 6-in. blocks. Surely the experiments conducted by Turner on the volume or rather linear, changes with the T test bar do not in any way represent the effect of the elements quoted on the volume changes of cast-iron on solidification.

An important factor controlling liquid shrinkage, and one that I have not been able to associate with chemical composition is the time taken during solidification, it being well known that the more rapidly molten iron solidifies, the lower the liquid shrinkage and the higher the degree of solidity throughout.

Effect of rate of cooling on solidity.—Photographs Q, R and S (page 280) represent three 6-in. blocks cast under identical conditions from the same ladle, total C. 3·28, Si 2·34, Mn 0·45, P 81, S 0·066. Q was cast into an exceptionally hard rammed-dry sand mould having a temperature of 150 deg. F. R, in a green sand mould containing 6·78 per cent. H_2O at 70 deg. F., and S in a



sand mould lined with 1-in. steel plate at a temperature of 150 deg. F. These photographs typically portray the effect of rate of cooling during solidification on solidity of castings of large bulk. The explanation commonly accepted for this peculiar phenomenon is that the rigidity of the chill mould reverses the direction of the natural expansion of high silicon and high phosphorous irons, whilst sand moulds give to it. There are three poignant factors against this hypothesis :—

1. The volume change of hard grey irons, 1·3 per cent. to 1·5 per cent. Si, 0·30 per cent. to 0·70 per cent. P., cast with the same degree of superheat, is practically the same as that of soft grey irons, 2 per cent. to 3 per cent. Si, of high or low P content, so far as piping is concerned.

2. That all irons cast in green sand moulds, which moulds possess an exceptionally low crushing strength, pipe less than dry sand or loam moulds which possess high crushing strength.

3. That the effect of temperature is more pronounced than chemical composition, *e.g.*, all irons pipe or draw if the metal is on the dull side, no matter what may be the rigidity, temperature or form of the mould.

Whilst it has not been possible to go into the question of liquid shrinkage to any length, it is hoped that the results of these experiments will serve to demonstrate the direction for future research, and that the question of solidity will receive more than a passing attention by all interested in the development of the science.

Solid Shrinkage.—By this is understood the contraction on cooling from immediate solidification to room temperature. During this period ordinary cast-iron suffers from two stages of heat fragility, the one, at a comparatively high temperature when some liquid phase exists, the other, at a low temperature ranging between 370 deg. and 520 deg. F.

If solidification of a casting be allowed to proceed uninterrupted, little trouble is encountered with the high temperature fragility, owing to the stretching capacity of cast-iron at these temperatures. In fact, this power to stretch is such that almost any grey iron casting may be made with rigid chills without any fear of cracking. On further cooling this stretch property falls and reaches a minimum at approximately 500 deg. F. the temperature at which cast-iron suffers an appreciable loss in strength. This is shown graphically by Fig. 4.

A represents an ordinary cylinder iron, B a 2 per cent. Si low P iron, and C a high Si high P iron.

From these curves it is obvious that although silicon and phosphorous do not affect the heat fragility of cast-iron, as will be shown later, they have an appreciable influence on the extensibility hot, which renders the use of permanent cores a practical proposition.

To demonstrate this in a more practical way a series of double T castings was made, fixing cast-iron bars, 2 in. by 1¼ in. section, in the mould, as shown by Fig. 5 The following irons were used :—

Alloy No.	C.c.	Gr.c.	T.c.	Si.	Mn.	P.	S.
1	0·65	2·60	3·25	1·43	0·72	0·42	0·108
2	0·58	2·59	3·17	2·00	0·70	0·10	0·092
3	0·46	2·78	3·24	2·00	0·60	0·80	0·092
4	0·52	2·62	3·14	2·59	0·67	1·75	0·046

casting each with 10 per cent. of superheat.

Alloy No. 1—	*Cupola Melted.*	
Experiment No. 1	Cast in green sand mould and allowed to cool undisturbed	Broke at 500 deg. F.
Experiment No. 2	Cast in green sand mould. Iron restricting supports removed at 1,100 deg. F. and the casting cooled slowly in a gas-heated muffle	Casting sound.
Alloy No. 2.		
Experiment No. 1	Cast in warm dry sand mould (temperature 150 deg. F.) and allowed to cool undisturbed	Broke at approximately 530 deg. F.
Alloy No. 3.		
Experiment No. 1	Cast in green sand. Allowed to cool undisturbed	Broke at 570 deg. F.
Experiment No. 2	Cast in warm dry sand mould. Allowed to cool undisturbed	Broke at 520 deg. F.
Experiment No. 3	Cast in green sand. Iron restricting supports removed at about 1,400 deg. F. and the casting allowed to cool in the open	Casting sound.
Experiment No. 4	Cast in warm dry sand (160 deg. F.). Restricting supports left in position but cooling slowly between two heavy iron blocks from 1,300 deg. F.	Casting sound.
Alloy No. 4.		
Experiment No. 1	Cast in warm dry sand mould at 120 deg. F. Restricting supports left in position	Casting sound.
Experiment No. 2	Cast in green sand. Restricting supports left in position	Casting sound.

These experiments require little comment. They clearly indicate the relation between composition and casting strains in castings of complicated form; and incidentally demonstrate that cracking in iron castings may be avoided by :—

1. Releasing or removing restricting cores whilst the casting is at a dull red heat.
2. By retarding the rate of cooling during the blue brittle range of temperature to a rate of approximately 10° C. per hour.
3. By accelerating cooling of heavier sections or retarding cooling of lighter section, if conditions do not permit the selection of an iron of high stretching capacity in the first place.

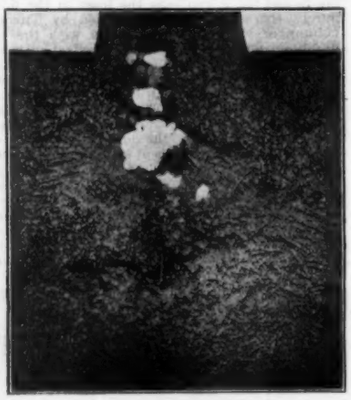


PHOTO. Q. CAST IN DRY SAND.

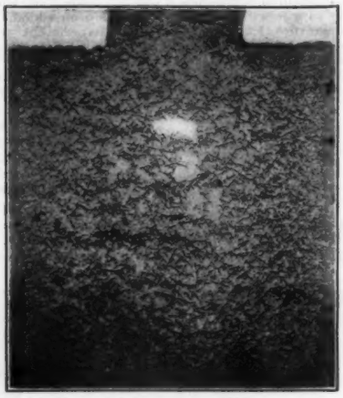


PHOTO. R. CAST IN GREEN SAND.

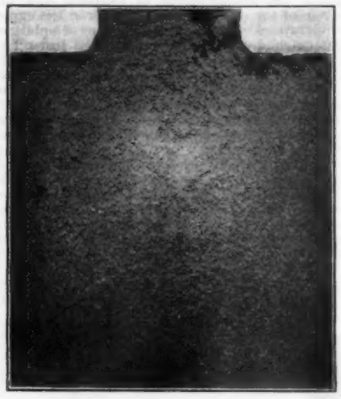


PHOTO. S. CHILL CAST.

TABLE I.

Mark.	C.c.	Gr.c.	T.c.	Si.	Mn.	P.	S.	Incipient Solidification.	Main Solidification.	Latent Heat of Solidification.	Phosphide Solidification.	Latent Heat Value.	Carbide Change.	Latent Heat Value.	Time in Minutes to Cool from Incipient Solidification to			
															Final Solidification.	End of Phosphor Change.	End of Carbide Change.	500 Deg. C.
								deg. C.	deg. C.	B.Th.U.	deg. C.	B.Th.U.	deg. C.	B.Th.U.				
1	0·66	2·74	3·4	1·03	0·63	0·09	0·063	1,243	1,160	49·0	960	1·5	736	25	43	73	176	640
2	0·60	2·67	3·27	1·15	0·62	1·54	0·086	1,221	1,125	39·0	957	17·0	738	20	34	80	167	605
3	0·73	2·15	2·88	1·27	0·55	0·47	0·096	1,232	1,153	38·0	955	5·5	747	31	32	79	171	590
4	0·72	2·39	3·11	1·50	0·71	0·52	0·097	1,210	1,142	48·0	955	6·0	738	22	37	72	155	570
Coe.	0 17	2·54	2·71	2·01	—	0·09	—	1,212	1,148	—	—	—	740	—	—	—	—	—
5	0·55	2·38	3·38	2·30	0·60	0·78	0·063	1,165	1,149	42·6	956	12·0	749	19	28	61	150	650
6	0·24	2·88	3·12	2·49	0·52	1·28	0·050	1,160	1,132	40·0	960	18·0	779	15	30	75	154	650

TABLE II.

Chemical Composition.								Tensile Tons per Square Inch.							
Mark.	C.c.	Gr.c.	T.c.	Si.	Mn.	P.	S.	From Temp. 70 Deg. F.	400 Deg. F.	500 Deg. F.	800 Deg. F.	860 Deg. F.	900 Deg. F.	1,200 Deg. F.	1,530 Deg. F.
1	0·60	2·66	3·31	1·50	0·74	0·49	0·112	17·75	16·5	16·2	—	—	17·1	7·0	2·44
2	0·60	2·41	3·08	2·00	0·57	0·096	0·089	17·8	—	16·3	18·2	—	15·8	6·9	2·41
3	0·37	2·88	3·25	2·24	0·67	0·77	0·107	13·2	11·5	10·2	—	13·6	—	5·2	—
4	0·15	3·5	3·65	2·92	0·49	1·26	0·062	12·0	—	9·9	—	11·2	12·4	4·96	—

EFFECT OF COMPOSITION ON THE STRENGTH OF CAST-IRON HOT.

One naturally hesitates to publish any data concerning the effect of any single variable on the physical properties of cast-iron, it being always problematic as to whether it is the effect of that variable or one of the many that inevitably creep in owing to the complications involved. At the best the results obtained from any investigation on cast-iron can only be comparative. Particularly does this apply to the tensile test which is controlled primarily by the form of the graphite carbon. Again, owing to the rapid deterioration of cast-iron by heat and our lack of knowledge of the mechanism of this deterioration, the problem of temperature effect as associated with the chemical composition of the various grades of irons now made is peculiarly difficult, and one feels very reluctant to express any views on the subject at all.

At the same time there exists a long-felt want for some reliable working knowledge of the behaviour of cast-iron under conditions where well-known growth phenomena does not enter into consideration, and it is because of this that these experiments have been carried out.

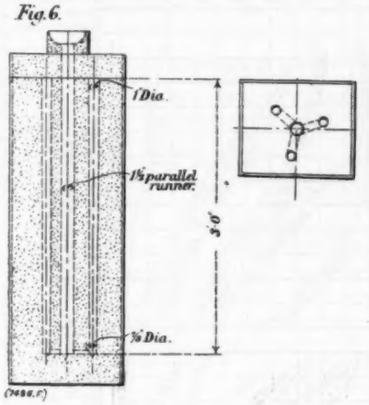
The irons given in the table under Fig. 8 were selected. Three 1-in. bars were cast from each into dry sand moulds as shown by Fig. 6, controlling both temperature of the metal and the mould. The form of the test-piece, the furnace used and method of measuring the temperature are shown by Fig. 7. Each test-piece was heated to the specified temperature as quickly as possible and retained at that temperature for exactly 1 hour before breaking.

The temperatures chosen were 70 deg., 400 deg., 500 deg., 800 deg., 860 deg., 900 deg., 1,200 deg. and 1,530 deg. F.; the lower temperatures, 400 deg. to 500 deg. F., to determine the loss in strength at the second period of heat fragility; the temperatures of 860 deg. and 900 deg. F. were selected because of the distinct halt found in the cooling curve of the cast-iron at about these temperatures; 1,200 deg. to 1,530 deg. F. were chosen because of the remarkable ductility of cast-iron when heated to a dull red. The results of the experiments are given in Table II, and shown graphically by Fig. 8, together with the curve plotted from the figures published by Rudeloff.

It will be observed that there is a striking similarity between each iron, whether of soft or high-tenacity grade, or whether high or low in phosphorous, the strength falling from 200 deg. to 500 deg. F., and rising to a maximum between 800 deg. to 900 deg. F. Above 900 deg. F. the strength rapidly falls away, and is under 2½ tons per square inch at 1,530 deg. F. (832 deg. C.), *i.e.*, between the carbide and phosphide change points—even in the strongest and toughest irons. These experiments, whilst by no means complete, enable a better understanding of the effect of temperature on the strength of cast-irons. They show the limitations of this material for internal-combustion engine parts where high temperatures are encountered, unless provided with a suitable arrangement for the dissipation of that heat. They explain the irregular behaviour of cast-iron when used for press tool and die work, and the breaking down of furnace castings, firepans, stove grates, kiln stirrer blades and ingot moulds. Together with a knowledge of the stretching capacity of cast-iron, they enable the designer and foundryman to predict the distribution

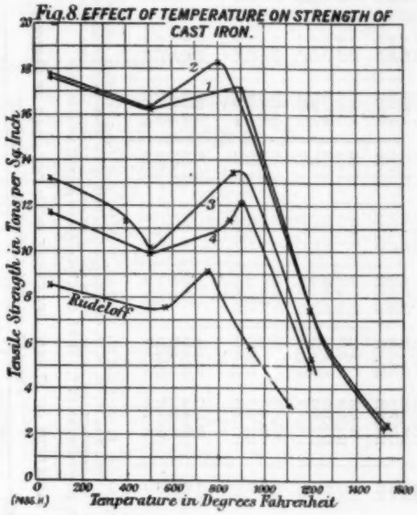
CAST IRON AND ITS CHEMICAL COMPOSITION.

Fig. 6.



(7488.F.)

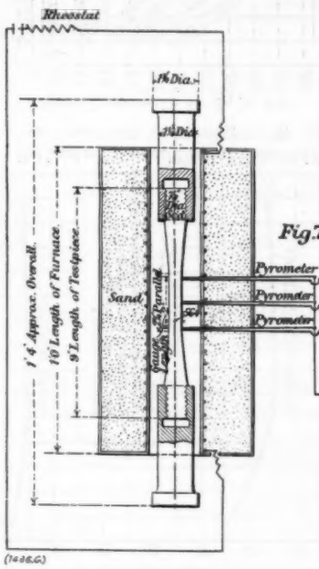
Fig. 8. EFFECT OF TEMPERATURE ON STRENGTH OF CAST IRON.



(7488.H.)

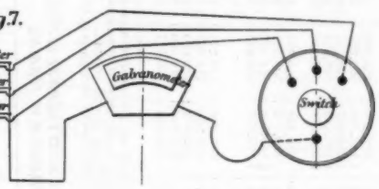
	C.c.	Gr.c.	T.c.	Si.	Mn.	P.	S.
1	0·60	2·66	3·31	1·5	0·74	0·49	0·112
2	0·60	2·41	3·08	2·0	0·57	0·096	0·089
3	0·37	2·88	3·25	2·24	0·57	0·77	0·107
4	0·15	3·5	3·65	2·92	0·49	1·26	0·062

Rudeloff not given.



(7488.G.)

Fig. 7.



and magnitude of the stress in a casting of complicated form, and furnish a working knowledge of the strength of any portion of a casting at the various stages during cooling in the mould, and so enable the necessary precautions to be taken in selecting the right time to release either mould or core or to remove chills without endangering the castings in any way.

DEPARTMENT OF SCIENTIFIC AND INDUSTRIAL RESEARCH.—Engineer Vice-Admiral Sir George Goodwin, K.C.B., late Engineer-in-Chief of the Fleet, and Dr. James Colquhoun Irvine, C.B.E., F.R.S., Vice-Chancellor and Principal of St. Andrew's University, have been appointed by an Order of Council dated August 10, to be members of the Advisory Council to the Committee of the Privy Council for Scientific and Industrial Research.

THE ROYAL SANITARY INSTITUTE.—This Institute has issued a pamphlet giving the courses of lectures and demonstrations for the coming autumn term. An introductory lecture will be delivered to the students by Louis C. Parkes, M.D., D.P.H., Chairman of the Council, on Monday, September 25, at 5.30 p.m. The pamphlet states the dates of the following lectures, and contains other information for the guidance of students.

HYDRO-ELECTRIC DEVELOPMENTS IN NEW ZEALAND.—Some time ago the New Zealand Government placed an order with Messrs. Vickers, Limited, for two Pelton turbines, which are now being erected on site. This order was followed by one for two Francis turbines, each of 3,100 h.p., to operate under a 27-ft. head, for the Hora Hora Power Station on the Waikato River. It is interesting to note also that the Metropolitan-Vickers Electrical Company, Limited, recently secured the orders for the 6,000 k.v.a. generators and 100,000-volt switch gear for the Mangahao Hydro-Electric Power Station in New Zealand. The two firms work in close co-operation on hydro-electric matters, and the former has the advantage in its water turbine department of long experience of Continental practice by association with one of the leading Swiss firms. The manufacture of the turbines is carried out at Barrow-in-Furness.

CATALOGUES.

Pyrometers.—A catalogue of radiation pyrometers received from the Thwing Instrument Company, 3339, Lancaster-avenue, Philadelphia, shows a large number of types, including indicating and multiple recording patterns.

Electrically Driven Machinery.—The A.C.E.C. of Belgium send from their London office, 56, Victoria-street, S.W. 1, a copy of their quarterly catalogue, containing descriptions of the winding, pumping and other machinery made by them.

Boiler House Measuring Instruments.—The Lea Recorder Company, Limited, 28, Deansgate, Manchester, send two carefully compiled catalogues, one describing their coal meters and the other their instruments for measuring feed water, sewage, tar, oil, &c.

Centrifugal Machines.—A catalogue illustrating 75 of their centrifugal machines, comprising one order for a cane sugar works in Java, has come from Messrs. Pott, Cassels and Williamson, Motherwell, Glasgow. Each machine is driven by a separate electric motor.

Electric Traction.—The camshaft control as applied by the English Electric Company, Limited, Queen's House, Kingsway, London, W.C. 2, to electric locomotives and electric motor coaches, is fully illustrated and described, and its advantages as compared with other control methods explained, in a special catalogue received from the firm.

Metal Saws.—A catalogue received from Messrs. Frys (London), Limited, 46, Upper Thames-street, London, E.C. 4, relates to hack saw blades, frames and hand and power sawing machines. The introductory remarks on hardness, tooth form and pitch, thickness, &c., will be helpful in choosing the saws that are best and most economical for any particular work.

Radial Drills.—The radial arm type of drilling machine fully maintains its place, with many adaptations of form and drive. One multiple form now made is practically a number of single machines with a common drive, and is particularly serviceable for gang work on girders and large plates. An excellent catalogue of this type of tool has come to hand from Messrs. Kitchen and Wade, Arundel-street, Halifax.

Vacuum Production and Measurement.—A 28-page pamphlet, explaining methods for producing and measuring vacua, has been received from the Pulsometer Engineering Company, Limited, Reading, and 11, Tothill-street, London, S.W. Copies of the pamphlet, which has been written by Mr. Henry A. Fleuss, may be obtained from Messrs. Poynder and Son, Gun-street, Reading, price 6d. each, post free.

Portable Electric Tools.—A new edition of their catalogue of electric tools has reached us from the Consolidated Pneumatic Tool Company, Limited, 170, Piccadilly, London, W. 1. It shows a full range of small portable machines, with the tools and appliances used with them. A special catalogue describing an electric heater for rivets for which improvement in speed and uniformity of heating are claimed has also been received.

Centrifugal Boiler Feed Pumps.—Electrically-driven centrifugal pumps for boiler-feed water are the subject of a special catalogue issued by Messrs. Drysdale and Co., Limited, Yoker, Glasgow, who have specialised in pumps for marine and land use. These pumps deliver the feed water at pressures of 250 lb. and 280 lb. per square inch in a steady stream well suited to the requirements of regulating and measuring instruments.

Nut Baling.—A pamphlet describing the process of baling certain nuts, for transport, by pressing them in their shells has been issued by the Hull Oil Manufacturing Company, Limited, and a copy has been forwarded to us by Messrs. Hollings and Guest, Limited, Thimble-lane, Birmingham, who make special machinery for the process. The bulk is reduced to half and the substitution of rectangular bales for bags, results in lower transport costs.

Small Locomotives.—A series of light steam locomotives for yard or contractors' work, and also for light railways, is illustrated with full particulars in a catalogue received from Messrs. Andrew Barclay, Sons and Co., Limited, Kilmarnock. The locomotives are made to standards in three sizes, to haul 109 tons, 155 tons, 240 tons on the level, and each size is made for four gauges, viz., 24 in., 2 ft. 6 in., metre and 3 ft. 6 in. They are intended for hard, rough work, both in this country and abroad.

Wire Rope Splicing.—A booklet on splicing wire rope, which is one of the class of catalogues that the practical man will be anxious to obtain, comes from Messrs. Brunton's, Musselburgh. It contains useful general information on the construction of wire ropes and their application to various requirements as well as illustrations of the various stages of splicing, &c., and of the tools for use in these operations. The text is well written, and it conveys as much information on the subject as words can.

Motor Wagons.—Two catalogues dealing with steam wagons and electric wagons are to hand from Clayton Wagons, Limited, Lincoln. These catalogues contain tables of figures comparing the working costs of horse vehicles, and three types of power vehicles, viz., petrol, steam and electric. The figures indicate that there are certain conditions in which any of the four types of vehicle may prove to be the most economical. It is well established that the steam wagon is very much more economical for continuous heavy haulage, but for certain classes of work the electric vehicle is unequalled.

Steam Traction Engines.—In addition to their other catalogues of road engines Messrs. Marshall, Sons and Co., Limited, Gainsborough, have issued a revised edition of a special catalogue of steam traction engines. These engines are made in four sizes with single cylinder and four sizes with compound cylinders. The nominal horse-powers by which they are still designated are 5, 6, 7, 8, in both types. The brake horse-powers, however, are about three and a half times the nominal horse-powers in the case of the single cylinder engines and nearly four times in the case of the compounds. In all types and sizes the speeds are 2 m.p.h. and 4 m.p.h. The engines are strongly built, with economical boilers, and are suitable for agricultural or general traction work.

Steel Piling Data.—The British Steel Piling Company, of Dock House, Billiter-street, London, E.C. 3, have reprinted the "Waistcoat Pocket" edition of excerpts from their general catalogue. The first issue of the booklet in question was published in 1917, and in making the new issue the proprietors have seized the opportunity of embodying in it a considerable amount of new matter and of bringing the contents fully up to date. In addition to very ample particulars as to the "Universal Joist" and "Simplex" steel piling, the volume contains a selection of mathematical tables and a collection of useful formulæ and graphical methods for determining the dimensions required in various cases. There are also a number of notes on pile driving and extraction, and some useful data as to various accessories.

TESTS OF A 60,000-KW. CROSS-COMPOUND TRIPLE-CYLINDER STEAM TURBINE.*

By HERBERT B. REYNOLDS and WALTER F. HOVEY, New York, N.Y., Associate Members.

(*Concluded from page* 248.)

Turbine Tests.—Although the turbine was first placed in complete operation on October 11, 1918, the tests were not run until July, 1921. The equipment used for conducting the turbine tests consisted of two large water tanks for measuring the steam consumption, three single-phase rotating standard watt-hour meters for measuring the output, and all the necessary thermometers, gauges and mercury columns for determining temperatures, pressures and vacua as recorded in this report.

The water-measuring tanks had a capacity of 300,000

* Paper read before the New York Section of the A.S.M.E., February, 1922.

TABLE I.—SUMMARY OF RESULTS OF TEST OF 60,000 KW. CROSS-COMPOUND TRIPLE-CYLINDER STEAM TURBINE.

Test No.	Load Average, Net Kw.	Duration, Hour.	Steam Pressure. Throttle, Abs. Lb. per Sq. In.	Steam Pressure. Throttle, Abs. Kg. per Sq. Cm.	Steam Pressure. Exhaust Vacuum* In. Hg.	Steam Pressure. Exhaust Vacuum* Mm. Hg.	Steam Temperatures at Throttle. Deg. F.	Steam Temperatures at Throttle. Deg. C.	Superheat. Deg. F.	Superheat. Deg. C.	Water. Actual Total. Lb.	Water. Actual Total. Kg.	Water. Corrected Total.† Lb.	Water. Corrected Total.† Kg.	Load Average, Net Kw.	Output, Gross Total, Kw.-Hr.	Excitation,‡ Kw.-Hr.	Output, Net Total, Kw.-Hr.	Load, Average, Net Kw. Low-Pressure Element Right, Kw.	Load, Average, Net Kw. High-Pressure Element, Kw.	Load, Average, Net Kw. Low-Pressure Element, Left, kw.	Water Rate Correction.† Lb. per Kw.-Hr.	Water Rate Correction.† Kg. per Kw.-Hr.	Rankine Cycle Efficiency,† per Cent.	Thermal Efficiency,† per Cent.
8	15,038	3	230·0	16·17	29·11	739·4	539·0	281·7	145·2	80·7	569,704	258,412	578,085	262,214	15,038	45,579	465	45,114	3,955	7,128	3,955	12·81	5·810	65·3	21·5
36	20,231	3	219·5	15·43	28·61	726·7	522·2	272·3	132·5	73·6	769,254	348,926	731,925	331,994	20,231	61,171	479	60,692	5,301	10,459	4,471	12·06	5·470	69·3	22·9
32	20,534	3	221·4	15·57	28·56	725·4	519·1	270·6	128·6	71·4	784,970	356,054	741,357	336,272	20,534	62,082	480	61,602	5,195	10,986	4,353	12·03	5·456	69·5	22·9
43	24,928	3	220·5	15·50	28·47	723·1	520·4	271·3	130·3	72·4	924,420	419,308	869,796	394,531	24,928	75,271	488	74,783	6,706	12,240	5,982	11·63	5·274	71·9	23·7
34	25,274	3	219·0	15·40	28·45	722·6	516·6	269·2	127·1	70·6	940,025	426,386	881,487	388,834	25,274	76,319	497	75,822	7,026	12,511	5,737	11·63	5·274	71·9	23·7
26	30,102	3	224·7	15·59	28·44	722·4	531·9	277·7	141·3	78·5	1,075,971	488,045	1,023,660	464,322	30,102	90,814	508	90,306	8,128	14,750	7,224	11·34	5·144	73·6	24·3
30	30,146	3	222·2	15·62	28·40	721·4	522·2	272·3	131·4	73·0	1,087,750	493,393	1,023,465	464,233	30,146	90,941	503	90,438	7,989	14,741	7,416	11·32	5·132	73·9	24·4
40	34,648	3	223·2	15·69	28·28	718·3	523·5	273·0	132·3	73·5	1,233,880	559,676	1,155,531	524,137	34,648	104,466	523	103,943	9,805	16,250	8,593	11·12	5·044	75·2	24·8
28	34,798	3	221·0	15·54	28·38	720·8	524·3	273·5	134·0	74·4	1,229,740	557,798	1,161,006	526,620	34,798	104,916	521	104,395	9,500	16,390	8,908	11·12	5·044	75·2	24·8
45	37,605	3	221·6	15·58	28·15	715·0	522·0	272·2	131·5	73·1	1,337,720	606,776	1,243,581	564,076	37,605	113,354	538	112,816	10,567	17,449	9,589	11·02	4·998	75·9	25·0
17	40,332	3	219·4	15·42	28·27	718·1	528·2	275·6	138·5	76·9	1,414,619	641,657	1,333,596	604,906	40,332	121,532	535	120,997	10,567	18,149	11,616	11·02	4·998	75·9	25·0
37	44,910	3	222·0	15·61	28·08	713·2	528·0	275·5	137·3	76·3	1,603,180	727,186	1,496,472	678,784	44,910	135,297	568	134,729	13,473	18,683	12,754	11·11	5·039	75·3	24·8
31	45,436	3	218·9	15·39	28·03	712·0	524·7	273·7	135·2	75·1	1,631,650	740,100	1,517,100	688,145	45,436	136,874	566	136,308	13,267	19,129	13,040	11·13	5·048	75·1	24·8
39	47,407	3	219·4	15·43	27·93	709·4	522·6	272·5	132·9	73·8	1,709,612	775,463	1,578,171	715,843	47,407	142,796	576	142,220	14,222	19,769	13,416	11·10	5·035	75·3	24·8
27	47,647	3	220·4	15·49	28·03	712·0	523·9	273·3	133·8	74·3	1,703,985	772,911	1,584,600	718,759	47,647	143,514	574	142,940	14,533	19,535	13,579	11·09	5·030	75·4	24·9
41	55,059	3	218·9	15·39	27·76	705·1	545·2	285·1	155·8	86·6	1,967,280	892,338	1,844,070	836,452	55,059	165,777	600	165,177	17,564	20,867	16,628	11·16	5·062	74·9	24·7
35	55,063	3	220·0	15·47	28·07	713·0	539·8	282·1	149·9	83·3	1,949,370	884,214	1,849,497	839,273	55,063	165,792	603	165,189	17,675	20,703	16,685	11·20	5·080	74·6	24·6
44	59,283	3	219·4	15·42	27·44	697·0	542·3	283·5	152·6	84·8	2,157,430	978,589	1,987,863	901,764	59,283	178,474	625	177,849	18,971	21,876	18,436	11·18	5·071	74·8	24·7
33	60,456	3	218·7	15·38	28·09	713·5	545·1	285·0	155·7	86·5	2,128,240	965,348	2,036,007	923,512	60,456	181,996	628	181,368	19,708	22,006	18,742	11·23	5·094	74·4	24·6
42‖	66,860	2	217·0	15·26	27·00	685·8	552·2	289·0	163·4	90·8	1,646,720	746,936	1,510,474	685,136	66,860	134,159	440	133,719	22,866	22,265	21,719	11·30	5·125	74·0	24·4
19‖	67,168	2	216·2	15·20	27·33	694·2	547·3	286·3	158·8	88·2	1,634,762	741,512	1,517,722	688,423	67,168	134,785	449	134,336	22,971	21,763	22,434	11·30	5·125	74·0	24·4
20‖	25,550	3	223·8	15·73	28·39	721·1	525·0	273·9	133·6	74·2	939,640	426,211	882,666	400,368	25,550	77,145	495	76,650	6,822	12,775	5,953	11·52	5·225	72·6	23·9
25‖	34,853	3	222·5	15·64	28·40	721·4	521·7	272·0	130·8	72·7	1,222,737	554,621	1,153,530	523,221	34,853	105,080	522	104,558	8,888	16,415	9,550	11·03	5·003	75·8	25·0
38‖	38,375	3	220·5	15·50	28·29	718·6	520·6	271·4	130·5	72·5	1,360,705	617,202	1,275,867	578,727	38,375	115,666	541	115,125	11,052	17,192	10,131	11·08	5·026	75·4	24·9
29‖	38,553	3	220·5	15·50	28·31	719·1	518·5	270·3	128·4	71·3	1,365,685	619,461	1,280,529	580,834	38,544	116,168	535	115,633	10,638	17,499	10,407	11·07	5·021	75·5	24·9
18‖	58,859	3	215·3	15·14	27·47	697·7	542·4	283·5	154·3	85·7	2,118,851	961,090	1,954,272	886,438	58,859	177,198	620	176,578	19,012	21,483	18,364	11·07	5·021	75·5	24·9
10¶	19,902	2	228·2	16·04	28·45	722·6	544·1	284·5	151·0	83·9	506,383	229,690	482,362	218,794	19,902	40,117	314	39,803	4,916	10,210	4,776	12·12	5·498	69·0	22·8
13¶	30,307	2	229·2	16·11	28·36	720·3	554·7	290·4	161·2	89·6	707,655	320,985	680,174	308,520	30,307	60,942	329	60,613	7,940	14,608	7,759	11·22	5·089	74·5	24·6
14¶	40,547	3	224·0	15·75	28·33	719·6	530·5	276·9	139·0	77·2	1,416,240	642,392	1,348,530	611,677	50,547	122,181	540	121,641	11,596	17,841	11,110	11·09	5·030	75·4	24·9
22**	39,316	3	221·5	15·57	28·34	719·8	519·9	271·0	129·4	71·9	1,366,777	619,954	1,287,672	584,075	39,316	118,480	532	117,948	11,009	17,810	10,497	10·92	4·953	76·6	25·3
7††	No load	1	227·9	16·02	28·34	719·8	550·0	287·8	155·0	86·1	32,428	14,709	—	—	No load	—	154	—	—	—	—	—	—	—	—
3‡‡	15,038	2	224·7	15·80	28·51	724·2	526·0	274·4	134·0	74·4	399,500	181,208	375,612	170,374	15,038	30,292	215	30,077	10,151	4,887	—	12·49	5·665	66·9	22·1
5‡‡	19,842	2	222·6	15·65	28·35	720·1	527·0	275·0	136·0	75·6	507,630	230,256	473,934	214,972	19,842	39,907	222	39,685	13,433	6,409	—	11·94	5·416	70·0	23·1
2‡‡	24,934	2	222·0	15·61	28·31	719·1	531·0	277·2	140·0	77·8	622,980	282,577	585,672	265,655	24,934	50,104	236	49,868	16,955	7,979	—	11·74	5·324	71·2	23·5
4‡‡	30,168	2	218·0	15·33	28·04	712·2	531·0	277·2	142·0	78·9	740,880	336,056	688,486	312,290	30,168	60,579	242	60,337	20,424	9,744	—	11·41	5·175	73·3	24·2
6‡‡	35,391	2	214·9	15·11	27·37	695·2	530·0	276·7	142·0	78·9	886,050	401,903	795,368	360,771	35,391	71,044	262	70,782	24,597	10,794	—	11·24	5·098	74·4	24·5

* Referred to 30-in. (762-mm.) barometer at 58·1 deg. F. (14·5 deg. C.). † As corrected to 220 lb. per square inch (15·47 kg. per square centimetre) absolute pressure, 150 deg. F. (65·6 deg. C.) superheat, 29-in. Hg. (736·6 mm.) vacuum, referred to 30 in. (762 mm.) barometer at 58·1 deg. F. (14·5 deg. C.). ‡ Including rheostat loss. § Tests Nos. 19 and 42 made with hand-operated quarternary valve wide open. ‖ Tests Nos. 18, 20, 25, 29 and 38 exceeding limit of variation from average, discarded. ¶ Test Nos. 10, 13 and 14 made with operating governor adjusted to limit maximum loads to values shown in second column. ** Test No. 22 made with secondary and tertiary valves out of service. †† Test No. 7 made without load on generators, with generator field currents adjusted to give normal voltage on open circuit. ‡‡ Tests Nos. 2, 3, 4, 5 and 6 made on high-pressure and right-hand low-pressure elements only, with left-hand low-pressure element out of service.

Fig. 9. WATER-RATE CURVES AND WILLANS LINE FOR 60,000 K.W. TURBINE

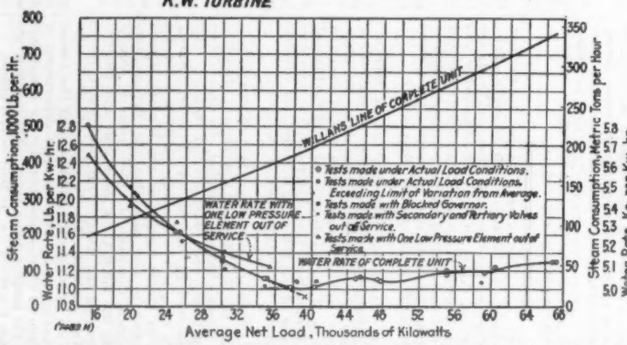

WILLANS LINE OF COMPLETE UNIT
WATER RATE WITH ONE LOW PRESSURE ELEMENT OUT OF SERVICE
WATER RATE OF COMPLETE UNIT
Tests made under Actual Load Conditions.
Tests made under Actual Load Conditions. Exceeding Limit of Variation from Average.
Tests made with Blocked Governor.
Tests made with Secondary and Tertiary Valves out of Service.
Tests made with One Low Pressure Element out of Service.
Steam Consumption, 1000 Lb. per Hr.
Water Rate, Lb. per Kw.-hr.
Steam Consumption, Metric Tons per Hour
Water Rate, Kg. per Kw.-hr.
Average Net Load, Thousands of Kilowatts

Fig. 9. Steam pressure, 220 lb. per square inch (15·47 kg. per centimetre) absolute; superheat, 150 deg. F. (65·6 deg. C.); vacuum, 29 in. Hg. (736·6 mm.) referred to a 30-in. (762 mm.) barometer; water rate factor 0·984. Curves based on tests Nos. 2 to 6 and 17 to 45 inclusive (excluding tests showing water rates differing from average curves by amounts exceeding 0·5 per cent., special tests with blocked governor, and test with secondary and tertiary valves out of service).

Fig. 10. RANKINE-CYCLE AND THERMAL-EFFICIENCY CURVES FOR 60,000 K.W. TURBINE

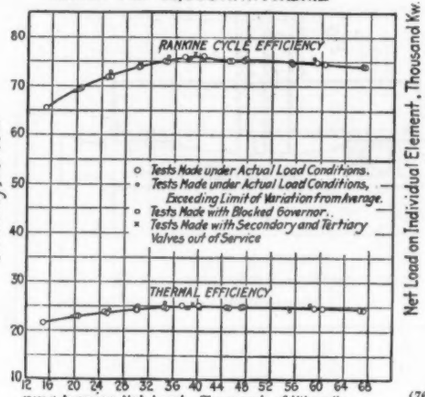
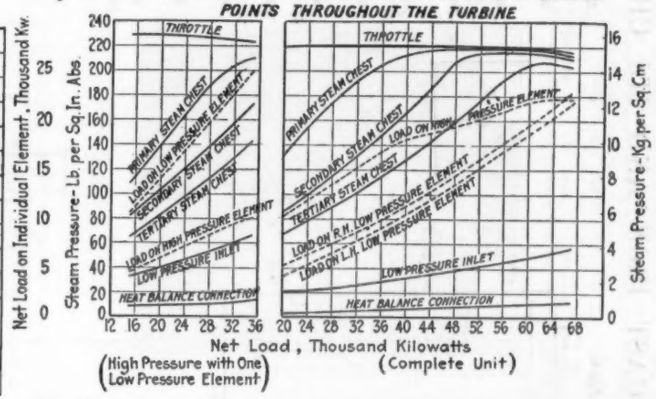

RANKINE CYCLE EFFICIENCY
THERMAL EFFICIENCY
Tests Made under Actual Load Conditions.
Tests Made under Actual Load Conditions, Exceeding Limit of Variation from Average.
Tests Made with Blocked Governor.
Tests Made with Secondary and Tertiary Valves out of Service
Efficiency, Per Cent
Average Net Load, Thousands of Kilowatts

Fig. 10. Steam pressure, 220 lb. per square inch (15·47 kg. per square centimetre) absolute; superheat, 150 deg. F. (65·6 deg. C.); vacuum, 29 in. Hg. (736·6 mm.) referred to a 30-in. (762-mm.) barometer. Curves based on tests Nos. 17 to 45, inclusive (excluding tests showing water rates differing from average curves by amounts exceeding 0·5 per cent., special tests with blocked governor and test with secondary and tertiary valves out of service).

Fig. 11. VARIATION OF STEAM PRESSURE WITH THE LOAD AT VARIOUS POINTS THROUGHOUT THE TURBINE


THROTTLE
PRIMARY STEAM CHEST
LOAD ON LOW PRESSURE ELEMENT
SECONDARY STEAM CHEST
TERTIARY STEAM CHEST
LOAD ON HIGH PRESSURE ELEMENT
LOW PRESSURE INLET
HEAT BALANCE CONNECTION
LOAD ON R.H. LOW PRESSURE ELEMENT
LOAD ON L.H. LOW PRESSURE ELEMENT
Net Load on Individual Element, Thousand Kw.
Steam Pressure - Lb. per Sq. In. Abs.
Steam Pressure - Kg. per Sq. Cm.
Net Load, Thousand Kilowatts
(High Pressure with One Low Pressure Element)
(Complete Unit)

lb. each. These tanks were very carefully calibrated before the tests by filling them with water weighed on platform scales. The condensate was measured throughout the tests, by alternating from one tank to the other, one tank being filled while the other tank was being emptied. Corrections were made for variation of the of 0·5 per cent. All thermometers and gauges were also calibrated in the usual manner. The specific gravity of the mercury used in the vacuum columns was determined and corrections made accordingly. The readings obtained from the mercury columns were further corrected for meniscus, temperature and barometer reading. The

Fig. 12. CURVES FOR CORRECTING STEAM CONSUMPTION TO THE STANDARD CONDITIONS

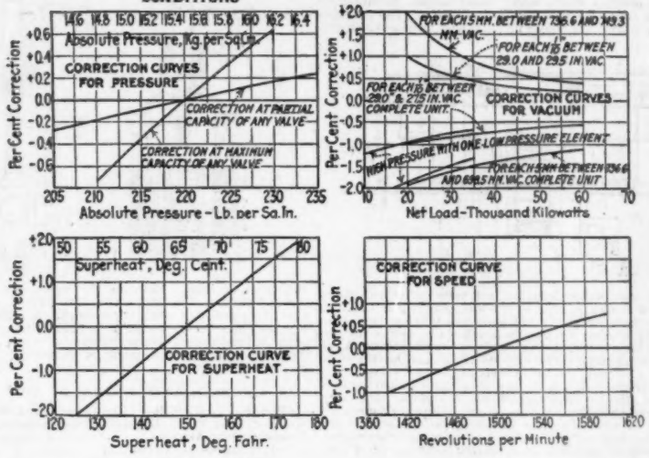
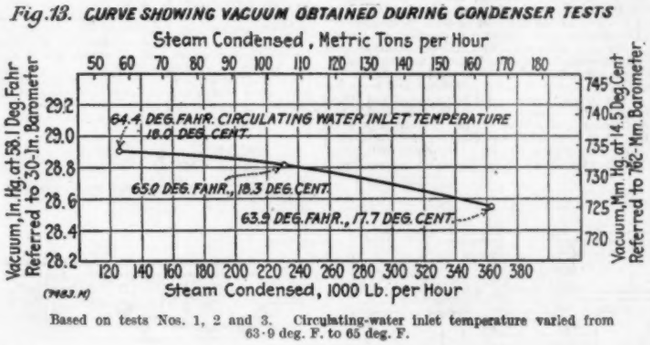

Absolute Pressure, Kg. per Sq. Cm.
CORRECTION CURVES FOR PRESSURE
CORRECTION AT PARTIAL CAPACITY OF ANY VALVE
CORRECTION AT MAXIMUM CAPACITY OF ANY VALVE
Per Cent Correction
Absolute Pressure - Lb. per Sq. In.
FOR EACH 5 MM. BETWEEN 736·6 AND 749·3 MM. VAC.
FOR EACH ½" BETWEEN 29·0 AND 29·5 IN. VAC.
FOR EACH ½" BETWEEN 28·0 & 27·5 IN. VAC. COMPLETE UNIT.
CORRECTION CURVES FOR VACUUM
WITH ONE LOW PRESSURE ELEMENT
FOR EACH 5 MM. BETWEEN 736·6 AND 685·8 MM. VAC. COMPLETE UNIT
Net Load - Thousand Kilowatts
Superheat, Deg. Cent.
CORRECTION CURVE FOR SUPERHEAT
Superheat, Deg. Fahr.
CORRECTION CURVE FOR SPEED
Revolutions per Minute

Fig. 13. CURVE SHOWING VACUUM OBTAINED DURING CONDENSER TESTS


Steam Condensed, Metric Tons per Hour
64·4 DEG. FAHR. CIRCULATING WATER INLET TEMPERATURE 18·0 DEG. CENT.
65·0 DEG. FAHR., 18·3 DEG. CENT.
63·9 DEG. FAHR., 17·7 DEG. CENT.
Vacuum, In. Hg. at 58·1 Deg. Fahr. Referred to 30-In. Barometer
Vacuum, Mm. Hg. at 14·5 Deg. Cent. Referred to 762-Mm. Barometer
Steam Condensed, 1000 Lb. per Hour

Based on tests Nos. 1, 2 and 3. Circulating-water inlet temperature varied from 63·9 deg. F. to 65 deg. F.

controlling the load subjected the turbine to the full swings of the railroad load. Two series of tests were run, one with the complete unit in service and the other with the high pressure and one low-pressure turbine in service.

Table I gives the numerical results of the turbine tests, while the performance is shown graphically in Figs. 9, 10 and 11. Fig. 9 gives the total steam consumption and water rate of the unit, while Fig. 11 gives the thermal and Rankine-cycle efficiencies. From these curves it will be seen that the lowest water rate obtained while operating the complete unit under normal conditions was 11 lb. per kilowatt-hour, while the highest Rankine and thermal efficiencies obtained were 76 per cent., and 25·1 per cent., respectively. With the high-pressure and one low-pressure turbine in service the lowest water rate was 11·25 lb. per kilowatt-hour. It will also be noticed in Fig. 9 that the water rate of the unit when the high-pressure and one low-pressure turbine is in service is better than that for the complete unit at loads below 25,000-kw.

A few tests were run with the governor blocked so that the unit operated under a steady load. These tests are shown in Figs. 9 and 10 by the small squares. It will be seen that there is no improvement in the efficiency under the steady load conditions at the loads selected for these tests. The test shown by the cross in Figs. 9 and 10 was run with the secondary and tertiary valves out of commission, while the load was adjusted so that the primary valve was wide open. As is to be expected, the lowest water rate was obtained while operating in this manner. Test No. 7 was run without any load on the generator, but with the field excited to give normal voltage on open circuit. The actual steam consumption per hour during this test amounted to 32,428 lb. No attempt was made to correct the steam consumption during this test, due to the load being outside the vacuum correction curves.

Fig. 11 shows the variation of steam pressure with the load at various points throughout the turbine. The curves in Fig. 12 were used for correcting the steam consumption to the standard conditions of 220 lb. absolute steam pressure, 150 deg. F. of superheat, 29 in. Hg. of vacuum and 1,500 r.p.m. These curves were furnished by the manufacturer, however the vacuum curves were checked to some extent by actual tests.

Water-Rate Factor.—In order to make an absolute and numerical comparison of the flatness of water-rate curves for different turbines, an expression has been used which is termed the "water-rate factor." Expressed mathematically,

$$F = \frac{M\,W}{C}$$

in which F = water-rate factor.
M = minimum water rate obtained.
W = mean load between one-half rated load and maximum load, which is the usual operating range.
C = average total steam consumption per hour covering the range between one-half rated load and maximum load.

Using the curves given in Fig. 11, substitutions may be made as below:

TABLE II.—SUMMARY OF CONDENSER TESTS.

Number of Test		3		1		2			3		1		2	
Duration of test	Hours	3		3		3		Hours.	3		3		3	
Barometer*	In. Hg.	30·17		30·20		30·15		Mm. Hg.	766·3		769·4		765·8	
Load on turbine, average	Gross kw.	20,200		40,100		60,233		Gross Kw.	20,200		40,100		60,233	
Superheat at turbine throttle	Deg. F.	108		118		121		Deg. C.	60·0		65·5		67·2	
Steam pressure, turbine throttle, absolute	Lb. per sq. in.	232		228		222		Kg. per Sq. cm.	16·31		16·03		15·61	
Temperature of circulating water in	Deg. F.	64·4		65·0		63·9		Deg. C.	18·0		18·3		17·7	
Air leakage per minute (both units)	Cub. ft. at 60 deg. F.	18·0		12·7		14·8		Cu. cm. at 15·5 deg. C.	510		360		419	
Number of air pumps in service	—	2		2		2			2		2		2	
Condenser Unit.		Left.	Right.	Left.	Right.	Left.	Right.		Left.	Right.	Left.	Right.	Left.	Right.
Average load, steam per hour	Lb.	119,333	132,667	224,333	236,333	345,667	380,000	Kg.	54,128	60,176	101,755	107,198	156,791	172,364
Vacuum average†	In. Hg.	28·80	29·01	28·81	28·82	28·55	28·57	Mm. Hg.	731·5	736·9	731·8	732·0	725·2	725·7
Temp. corresponding to vacuum	Deg. F.	84·8	78·8	84·5	84·2	90·7	90·3	Deg. C.	29·3	26·0	29·2	29·0	32·6	32·4
Temp. primary heater discharge	Deg. F.	77·7	75·1	79·4	78·8	83·7	84·0	Deg. C.	25·4	23·9	26·3	26·0	28·7	28·9
Temp. hotwell discharge	Deg. F.	71·0	69·6	75·9	75·5	80·1	79·8	Deg. C.	21·7	20·9	24·4	24·2	26·7	26·6
Temp. rise in primary heater	Deg. F.	6·7	5·5	3·5	3·3	3·6	4·2	Deg. C.	3·7	3·0	1·9	1·8	2·0	2·3
Temp. of circulating water out	Deg. F.	67·6	67·9	70·5	70·9	72·9	73·3	Deg. C.	19·8	19·9	21·4	21·6	22·7	22·9
Temp. rise of circulating water	Deg. F.	3·2	3·5	5·5	5·9	9·0	9·4	Deg. C.	1·8	1·9	3·1	3·3	5·0	5·2
Circulating water (two pumps running)	Gal. per min.	69,200	70,600	74,000	72,700	70,500	74,100	Lit. per min.	262,000	267,300	280,100	275,200	266,900	280,500
Heat transferred per hour:	1,000 B.Th.U.							1,000 kg.-cal.						
Primary heater section	—	799·53	729·67	785·17	779·90	1,244·4	1,596·0	—	201·48	183·88	197·86	196·54	313·59	402·19
Condensing section	—	110,800	123,580	203,380	214,400	316,980	348,350	—	27,922	31,130	51,252	54,029	79,879	87,784
Entire condenser surface	—	111,600	124,260	204,170	215,180	318,220	349,940		28,123	31,314	51,451	54,225	80,191	88,185
Heat transferred per hour per unit surf.:	B.Th.U. per sq. ft							Kg.-cal. per sq. m.						
Primary heater section	—	333	304	327	325	519	665	—	903	824	887	881	1,408	1,803
Condenser section	—	2,328	2,595	4,273	4,504	6,659	7,318	—	6,314	7,038	11,588	12,224	18,059	19,846
Entire condenser surface	—	2,232	2,485	4,083	4,304	6,634	6,999	—	6,053	6,735	11,075	11,672	17,259	18,981
Mean temp. difference (log.):	Deg. F.							Deg. C.						
Steam to condensate	—	10·07	6·04	6·70	6·92	8·67	8·22	—	5·59	3·36	3·72	3·84	4·82	4·57
Steam to circulating water	—	18·73	12·58	16·59	16·06	21·98	21·35	—	10·41	6·99	9·22	8·02	12·21	11·86
Heat transferred per hour per unit surface per deg. M.T.D.:	B.Th.U. per sq. ft							Kg.-cal. per sq. m.						
Primary heater section	—	33	50	49	47	60	81	—	161	245	239	229	293	395
Condensing section	—	124	206	257	280	903	343	—	606	1,007	1,256	1,370	1,480	1,675

* Barometer, in. Hg. (mm. Hg.) at 58·1 deg. F. (14·5 deg. C.). † Vacuum, in. Hg. at 58·1 deg. F. (mm. Hg. at 14·5 deg. C.) referred to 30 in. (762 mm.) barometer.

temperature of the water. Corrections were also made for condenser leakage, which amounted to only about 0·05 per cent. This leakage was determined by titration. The rotating standard watt-hour meters which were used for measuring the output were calibrated several times throughout the tests by the Electrical Testing Laboratories, New York City. It is believed that both the input and output were measured within an accuracy

barometer reading was obtained from the local United States Weather Bureau.

Most of the tests were of 3 hours' duration. With the exception of a few special tests, the turbine was operated under normal conditions, in so far as type of load was concerned. The load was controlled from the switchboard through the remote governor-control system provided for that purpose. This method of

$$F = \frac{11 \times 50{,}000}{558{,}925} = 0{\cdot}984.$$

Condenser Tests.—Separate tests were run in order to determine the performance of the condenser. The results of these tests are shown in Table II, while the curve given in Fig. 13 shows the relation between load and vacuum for the entire unit.

"ENGINEERING" ILLUSTRATED PATENT RECORD.

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The number of views given in the Specification Drawings is stated in each case; where none is mentioned the Specification is not illustrated.

Where inventions are communicated from abroad, the Names, &c., of the communicators are given in Italics.

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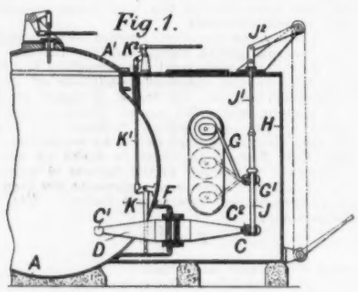
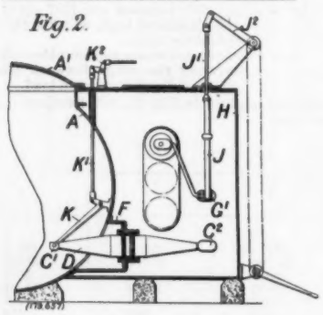
Any person may, at any time within two months from the date of the advertisement of the acceptance of a Complete Specification, give notice at the Patent Office of opposition to the grant of a Patent on any of the grounds mentioned in the Acts.

ELECTRICAL APPARATUS.

179,657. A. Reyrolle and Co., Limited, Hebburn-on-Tyne, H. W. Clothier, Wallsend-on-Tyne, and F. N. Linstow, Hebburn-on-Tyne. Electric Switch Gear. (4 *Figs.*) February 10, 1921.—This invention relates to switch gear for high voltage systems where the main break switches and isolating switches are all oil immersed and where the operative parts of the main switches can be withdrawn from the tanks which contain them for purposes of inspection or repair. A is a tank adapted to contain oil and having a cover A^1 from which a main switch is suspended. This main switch is not illustrated, but when in its operative position, *i.e.*, when the cover is closed, one of the switch arms makes electric connection with a fixed contact C^1 at the inner end of a conductor C, which passes through an insulator D held in a gland. This gland closes a chamber F which may be regarded as an extension of the main tank A.

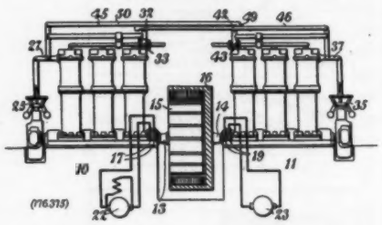




At the other end of the conductor C is another contact C^2 in the form of a socket in line with another socket G^1, which is joined to a bus-bar connection G. The bus-bar connection G, its socket G^1 and the socket C^2 are all contained in a chamber H, in which is a plug connection J, which, by means of a rod J^1 and an arm J^2, can be operated from outside the chamber to make connection between the bus-bar contact G^1 and the socket C^2 (Fig. 1), or to isolate the socket C^2, and consequently the contact C^1, from the bus-bar connection (Fig. 2). Within the tank A is a pivoted arm K, movable by means of a rod K^1 and mechanism K^2 into the two positions shown in Figs. 1 and 2. In the position illustrated in Fig. 1 when the conductor C is connected to the bus-bar by the plug connection J, the arm K is out of action, but when the conductor C is isolated as in Fig. 2, the arm K can be moved to make connection with the contact C^1 and earth it. (*Sealed.*)

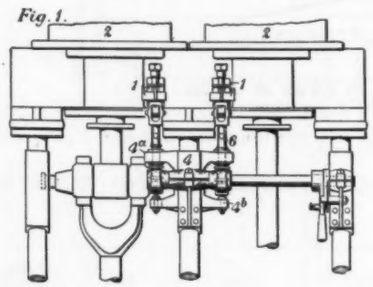
GAS ENGINES, PRODUCERS, HOLDERS, &c.

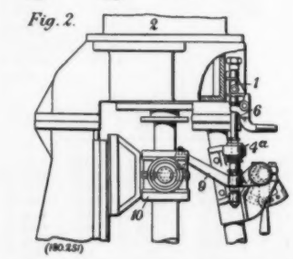
176,375. Metropolitan-Vickers Electrical Company, Limited, Westminster (*Assignees of A. T. Kasley Essington, Pennsylvania, U.S.A.*). **Multiple-Motor Power Plants.** (2 *Figs.*) March 3, 1922.—This invention relates to governing mechanism for multiple motor power plants, more particularly of the marine type. According to the present invention, each engine is provided with a governor, together with mechanism whereby each governor is capable of regulating the speed of the engine with which it is associated and at times is capable of co-operating with the other engine so that, when there is a drop in the power of the engine with which the governor is associated, the power of the other engine will be decreased, if necessary. Two engines 10, 11 are disposed with their crankshafts 13, 14 axially aligned. The electric generator has its rotatable elements carried by the axially-aligned crankshafts. The crankshaft 13 has mounted thereon a field element 15. The crankshaft 14 is provided with an armature element 16. Slip rings 17 are mounted on the crankshaft 13 and are connected to the field element and, through brushes, to an exciter 22. The armature element 16 furnishes current to an electric motor 23 through slip rings 19. In the present invention a governor mechanism is provided for each engine which is capable of controlling its speed and consequently its normal torque; however, should the governor mechanism of one engine be unable to control the engine with which it is associated so as to develop a torque substantially equal to the torque of the other engine, then a connection will be brought into play between the governor and the fuel valve of the other engine so as to throttle or restrict the flow of fuel thereto, thereby diminishing its torque. The governor 25 operates the valve lever 32 of the fuel valve 33. The governor 35 operates the fuel valve lever 42 of the fuel valve 43. Should the engine 11 tend to overspeed, the governor 35 will operate the fuel valve in a direction to throttle or restrict the fuel inlet and consequently check or reduce the speed. In case the engine 11 should slow down, the fuel valve is opened wider. Means are provided whereby the engines are so controlled as to develop substantially equal torques in order to operate satisfactorily the form of generator shown. This function is accomplished by inter-connecting linkages, whereby, should



the torque of one engine drop, its fuel valve is opened wider and wider and finally a limit is reached, whereupon the fuel valve of the other engine is acted upon to diminish its supply of motive fluid, thereby tending to equalise the torques of the engines. The inter-connecting mechanisms comprise links 45, 46 pivoted to arms of the bell crank levers 27, 37, and having ends 49, 50 which overhang the upper ends of the fuel valve levers 42, 32, respectively. It is necessary that there should be lost motion between the overhanging ends 49, 50 and the fuel valve levers 42, 32, so that the governor of one engine may open its fuel valve up to a certain point before operating through the link 45 or 46 to close partially the fuel valve of the other engine in order to produce equalisation of driving torques. (*Sealed.*)

180,251. N. R. Cooper, Dundee, and T. B. Cooper, Dundee. Fuel Pumps. (3 *Figs.*) August 20, 1921.—This invention has reference to internal-combustion engines of the Diesel or semi-Diesel type. For a Diesel or semi-Diesel engine, in accordance with this invention, fuel pump operating gear comprises the combination with a fuel pump and the engine crosshead, of a lever extending below the pump piston or plunger rod and into the line of movement of the crosshead and actuated by movement of the latter, this lever not being connected either with the pump piston or plunger rod or the crosshead. The pump cylinders 1 are mounted each on the cylinder 2 it is to supply with fuel. 4 is a member mounted on the standard 5 of the engine and carrying arms 4*a*, 4*b*. The pump cylinders 1 are mounted each directly above an arm 4*a*. The pump piston

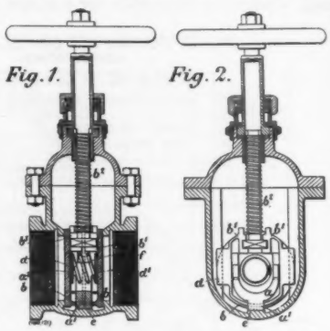




rods 6 extend downwards to and pass through the arms 4*a*. 9, 9, are the levers by which the piston rods 6 are operated. The levers 9 are pivoted at one end, and each extends towards the centre line of the engine, passing between an upper arm 4*a* and a lower arm 4*b*, and below the piston rod 6 it is to operate. Each of the levers 9 is of such length that, normally, its free end lies in the path of movement of a crosshead 10. In the upward movement of a crosshead 10, it contacts with the end of the lever lying in its path and causes the lever to move about its pivot in an upward direction. In its upward movement the lever contacts with its co-operating piston rod, and causes the piston within the pump cylinder to move and force the fuel contained therein into the engine cylinder 2 with which it is in connection. (*Sealed.*)

HYDRAULIC MACHINERY.

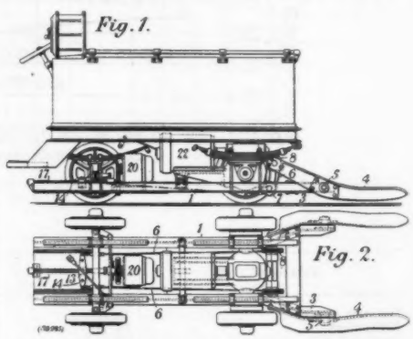
180,121. Sir J. Dewrance, K.B.E., Southwark. Gate Valves. (4 *Figs.*) March 17, 1921.—This invention relates to an improved gate valve of the type wherein two discs are forced against their respective seatings by means of inclined members, which become operative as the valve approaches its fully-closed condition. According to the improved method of construction, a forked or Y-shaped member *e* is freely mounted within a cage comprising lugs *b*, b^1, which project from the backs of the respective valve discs *d*, *d*. The stem a^1 of the member projects through the cage to a point slightly beyond the periphery of the discs. The arms of the Y-shaped member are formed with the usual wedges a^2, a^2, which, when the valve is nearly closed, abut against the corresponding inclined faces d^1, d^1 formed directly upon the backs of the valve discs *d*, *d*. In this condition, the projecting extremity of the stem of the Y-shaped member seats upon a fixed stop *e* in the floor of the valve casing; and, as the closing of the valve is completed, the wedging action forces the valve discs *d*, *d* apart and presses them firmly home upon their



respective seatings. Between the valve discs is arranged a spring *f* adapted to maintain the valve discs in sweeping contact with the faces over which they work, the forked form of the Y-shaped member embracing or straddling the spring. The backs of the valve discs are also provided with lugs b^1, b^2 for engaging the head of the screwed spindle *b*, whereby the valve discs are operated. (*Sealed.*)

LIFTING AND HAULING APPLIANCES.

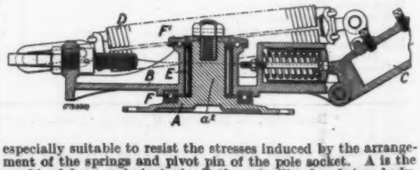
179,985. J. B. Wilkie, Liverpool, F. B. Converse, Westminster, and F. E. Bagnall, Westminster. Lifting and Transporting Articles. (2 *Figs.*) January 17, 1921.—This invention relates to lifting and transporting apparatus of the kind comprising a wheeled truck, a movable support carried thereby for the article to be lifted, and means for raising and lowering the support for the purpose of loading, transporting and unloading the article. The present invention consists broadly of an apparatus comprising a self-propelled vehicle having more than one pair of wheels and means associated with the vehicle for lifting the articles comprising a pair of arms pivoted to turn about horizontal axes and arranged one on each side of the centre line of the vehicle with their free extremities projecting beyond one end of the same and adapted to support the articles, and mechanical means directly connected to and



operating immediately upon the arms for turning them in a vertical plane about their pivots to cause the outer ends of the arms to move relative to the vehicle and raise the positioned load clear of the ground. The apparatus illustrated consists of an electrically-propelled truck having a girder frame 1 extended at the front end 3 to constitute a support for lifting arms 4, which are fulcrummed at 5 to the extended part 3 of the frame at or about their centres. The arms 4 are moved simultaneously about their fulcrums by wire ropes 6 passed round pulleys 7, 8. The pulleys 8 are mounted upon a shaft journalled in the inner ends of the lifting arms. The ropes 6 are attached to the extremities of a yoke 14 carried by a nut 13 on a screw 17. The screw is rotated by an electric motor 20. The body of the truck 21 is used as a compartment for storage batteries for supplying current to the motor 20 and to a main driving motor 22. (*Accepted May* 31, 1922.)

RAILWAYS AND TRAMWAYS.

179,996. P. Priestley, Liverpool. Trolley Pole Attachments. (15 *Figs.*) February 7, 1921.—This invention relates to trolley pole attachments of the type in which the swinging pole carrying plate is mounted to pivot in a stationary base and is provided with ball bearings interposed between the fixed base and swinging plate. According to the present invention, the bearing is formed of a combination of two ball bearings and an intermediate roller bearing which render the construction



especially suitable to resist the stresses induced by the arrangement of the springs and pivot pin of the pole socket. A is the combined base and pivot pin, B the swivelling bracket or body, C is the trolley pole socket, and D are the springs. The circular attachment flange A is bolted to the car top so as to be rigidly fixed thereto and is formed integral with the main pivot pin a^2. The pivotal connection between the bracket B and the pin a^2 is made by means of a roller bearing E and ball bearings F and F^1. (*Sealed.*)